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AGRICULTURAL TERRORISM (AGROTERROR) AND ESCALATION THEORY

by

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AGRICULTURAL TERRORISM (AGROTERROR) AND ESCALATION THEORY

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ABSTRACT

The debate about whether sub-state actors have an interest in conducting a WMD attack using chemical or biological weapons is embedded within escalation theory, which holds that in order to maintain credibility terrorist groups must demonstrate a continued ability to conduct operations and inflict significant numbers of casualties on their enemy, maintaining a consistent, if not escalating, level of violence. This thesis uses *E. coli* in produce and foot and mouth disease in livestock case studies to evaluate U.S. Systems' ability to contain such an agroterror attack and to estimate likely results of such attacks. The analysis shows that neither a FMD attack on livestock nor an *E. coli* attack on produce is likely to cause sufficient casualties, economic disruption, and/or fear and panic to constitute escalation from recent conventional attacks for an established international terrorist organization, and therefore agroterror attacks are not likely to be particularly attractive for such organizations.

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I. ESCALATION AND AGROTERRORISM

> The goal of agroterrorism is not to kill cows or plants. These are the means to the end of causing economic damage, social unrest, and loss of confidence in government.[1]

> Early detection of bioterrorist events is essential because although most diseases caused by bioterrorist threat agents are rapidly fatal, any are readily treatable and/or preventable with timely administration of appropriate antibiotics, antisera, vaccination, and/or prophylaxis following exposure.[2]

A. PURPOSE

Nearly six years after the devastating attacks of September 11, 2001, terrorism remains a great threat to the United States. There has been much speculation about the nature of the next attack, and whether it will be another innovative conventional attack using explosives of some type or whether it might be something unconventional, using a weapon of mass destruction (WMD).[3] If the next attack is of a chemical or biological nature, both the range in character of the attacks and potential impact are quite significant. With the arrest of Jose Padilla in 2002, it became apparent that anti-American terrorist groups like Al Qaeda had no compunction against pursing a “dirty bomb” that would spread radioactive material within the United States. Other attacks might be against physical infrastructure such as power grids, or cyber-terrorism against critical computer networks. The establishment of the Department of Homeland Security (DHS) and centralization of many antiterrorism responsibilities has shown the U.S. is making progress in many aspects of the prevention and response to terrorism; however, with respect to America’s vulnerability to an unconventional attack, debate continues over what form an unconventional terrorist attack would most likely take (nuclear,

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[1] Jim Monke, “Agroterrorism: Threats and Preparedness,” Washington, D.C.: Congressional Research Service, Library of Congress, August 25, 2006, ii, http://www.nationalaglawcenter.org/assets/crs/RL32521.pdf (accessed October 16, 2007).

[2] State of California, “Bioterrorism Surveillance and Epidemiologic Response Plan,” January 2002, 5.

[3] See the collection of essays in Russell Howard, James Forest, Joanne Moore, *Homeland Security and Terrorism; Readings and Interpretations*, (New York: McGraw-Hill, 2006).

chemical or biological), and what the most likely targets would be (people or agriculture). This thesis will evaluate the existing systems for prevention and response as well as the likely impact of an attack on agriculture.

B. IMPORTANCE

U.S. agriculture is a robust part of the global economy, generating more than $1 trillion a year, with more than $50 billion resulting from agricultural exports in 2005, estimated to increase to $77 billion in 2007 and nearly $95 billion in 2016.[4] Net U.S. farm income in 2006 was assessed at $60.6 billion and is expected to increase to an average of $66.7 billion annually over the next 10 years.[5] The U.S. remains the leading exporter of numerous agricultural products such as, wheat, corn, soybeans and cotton.[6] U.S. meat exports are expected to increase approximately 20% in the next 8 years,[7] reaching nearly 27 billion pounds in 2007 and exceeding 28 billion pounds by 2016.[8] These figures represent approximately 13.9 percent of the U.S. GNP.[9]

Modern terrorists have shown a not only an acceptance of unconventional methods, but also a desire to undertake new and dramatic attacks on the West, and American agriculture presents a robust, diversified, and accessible target. "Because of its breadth, diversity, and unparalleled success, US agriculture is an inviting target for terrorists."[10] A terrorist attack on U.S. agriculture could have far reaching impact; a successful infection of a type of crop or livestock could have dramatic impact on its

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[4] United States Department of Agriculture, "USDA Long-Term Agricultural Projection Tables," USDA Economics, Statistics, and Market Information System, February, 2007, http://usda.mannlib.cornell.edu/MannUsda/viewStaticPage.do?url=http://usda.mannlib.cornell.edu/usda/ers/94005/./2007/ accessed August 15, 2007, United States Government Accountability Office, "Homeland Security: Much is Being Done to Protect Agriculture from a Terrorist Attack, but Important Challenges Remain," (Washington, D.C.: GAO, 2005) (accessed November 22, 2006), 1.

[5] United States Department of Agriculture; "Agricultural Baseline Projections: U.S. Agricultural Sector Measures, 2007-2016," USDA Economic Research Service, http://www.ers.usda.gov/Briefing/Baseline/agsector.htm (accessed August 15, 2007).

[6] See attached graphs at Appendix A.

[7] See attached graph at Appendix B.

[8] "USDA Long-Term Agricultural Projection Tables."

[9] Jason B. Moats, *Agroterrorism; A Guide for First Responder,* (College Station: Texas A & M University Press), 2007, 5.

[10] Henry S. Parker, "Agricultural Bioterrorism: A Federal Strategy to Meet the Threat," (Washington D.C.: Institute for National Strategic Studies, National Defense University, 2002), vi.

marketability, and a successful attack would undermine American confidence in the effectiveness of the government to protect them against terrorism and specifically safeguard their food supply. Thus, it is crucial that an intelligent assessment of U.S. preparedness against the threat of a CBW attack on agriculture be made.

C. LITERATURE REVIEW

Before the 2001 U.S. anthrax letter attacks, experts in the field of chemical and biological terrorism wrote assessments arguing that the challenges of obtaining, developing, weaponizing, and dispensing effective levels of either chemical or biological agents were too great for a non-state actor such as a terrorist group to overcome. Analysis presented by authors like Jonathan Spyer, Jonathan Tucker and John Parachini pointed to the technological hurdles of creating an effective CBW program.[11] In a 2001 Rand report Parachini stated: "Terrorist groups and individuals historically have not employed biological weapons because of a combination of formidable barriers to acquisition and use and comparatively readily available alternatives and disincentives."[12] Even the most successful terrorist chemical attack only killed twelve people and injured several hundred. Compared to the more devastating conventional attacks like those of September 11th, historical CBW attacks cause casualties more on the order of magnitude of a single suicide bomber. Parachini noted that while states have long histories of robust CBW programs, "handling virulent materials and fashioning them into weapons capable of producing mass casualties is beyond the reach of most sub-national groups or individuals."[13] Other experts in the field of CBW discussed the specific hurdles sub-state

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[11] See analysis presented in Jonathan Spyer, "The Al-Qa'ida Network and Weapons of Mass Destruction," Open Source Center, September 1, 2004, http://opensource.dni.sgov.gov/cgi-bin/cgcgi (accessed June 1, 2007), *Toxic Terror; Assessing Terrorist Use of Chemical and Biological Weapons*, Jonathan B. Tucker, ed, MIT Press; Cambridge, 2000, and John Parachini's 2001 testimonials before Congress such as "Combating Terrorism: Assessing the Threat of Biological Terrorism," Statement of John Parachini, Policy Analyst, RAND Washington Officer, October 12, 2001, http://www.rand.org/pubs/testimonies/2005/CT183.pdf (accessed June 19, 2007).

[12] John Parachini, "Anthrax Attacks, Biological Terrorism and Preventive Responses," *RAND Publication CT -186*, November 6, 2001, http://www.rand.org/pubs/testimonies/2005/CT186.pdf (accessed June 19, 2007).

[13] John Parachini, "Combating Terrorism: Assessing the Threat of Biological Terrorism," Statement of John Parachini, Policy Analyst, RAND Washington Officer, October 12, 2001, http://www.rand.org/pubs/testimonies/2005/CT183.pdf (accessed June 19, 2007).

groups face with the development of both chemical and biological weapons.[14] "Acquiring a deliverable CBW capability requires terrorists to overcome a series of major hurdles: gaining access to specialized chemical ingredients or virulent microbial strains; acquiring equipment and know-how for agent production and dispersal; and creating an organizational structure capable of resisting infiltration or early detection by law enforcement."[15] Even should a group overcome development challenges, effective dissemination of both types of agents was seen to pose additional challenges. "Crude delivery methods are likely to remain the most common forms of CBW terrorism. They are potentially capable of inflicting at most tens to hundreds of fatalities…but not the mass death predicted by the most alarmist scenarios."[16] Effective vaporization of chemicals is difficult, and challenges of producing a certain spore size or preventing dilution of biological agents are especially complicated. Thus, these scholars concluded that while states should be aware of the potential threat of a CBW attack, the greater risk continued to be from a conventional attack, even if it relied upon unconventional methods like the airplanes used as guided missiles during the September 11th attacks. However, with significant changes in terrorist tactics, goals, and capabilities, most prominent experts have now revised their assessments.

The 2001 anthrax attacks changed the consensus on the sub-state WMD threat. While analysts continue to acknowledge that there are still significant challenges for a non-state actor in obtaining, developing, weaponizing and dispensing effective levels of either chemical or biological weapons, they now recognize that modern terrorist groups such as Al Qaeda have the means and patience to pursue active WMD programs, and are attracted by certain aspects of using CBW in an attack. While "[i]t was once generally believed to be too difficult for terrorists to produce sophisticated biological weapons and too risky for states to use them clandestinely against the United States," recent efforts by terrorist groups (especially al Qaeda) have demonstrated significant progress in

[14] See specifically Jonathan B. Tucker, "Introduction," in *Toxic Terror; Assessing Terrorist Use of Chemical and Biological Weapons*, Jonathan B. Tucker, ed, MIT Press; Cambridge, 2000, 6-7.

[15] Jonathan B. Tucker, "Lessons from the Case Studies," in *Toxic Terror; Assessing Terrorist Use of Chemical and Biological Weapons*, Jonathan B. Tucker, ed, MIT Press; Cambridge, 2000, 253.

[16] Tucker, "Lessons from the Case Studies," 253.

overcoming many of the hurdles historically identified in earlier analyses.[17] John Parachini wrote in November 2001: "The sophisticated quality of the Anthrax used in the letter sent to Senator Daschle suggests that the bioterrorism threat has reached a new level previously viewed by many analysts, myself included, as possible, but unlikely."[18]

There is now a consensus in the literature that CBW agents are within reach of terrorist groups.[19] However, there continues to be a debate about whether sub-state actors have an interest in conducting a WMD attack using chemical or biological weapons, and if so, what the most likely targets are. This debate is embedded within escalation theory, which holds that in order to maintain credibility terrorist groups must demonstrate a continued ability to conduct operations and inflict significant numbers of casualties on their enemy, maintaining a consistent, if not escalating, level of violence.[20] Proponents of escalation theory hold that Al Qaeda would lose legitimacy if it attempted another large-scale attack and failed, which would likely have severe repercussions on recruiting, fundraising, and global support from other extremist groups.[21] However, there is a debate within the literature on escalation about the likely impact, and therefore the appeal, of WMD attacks by terrorists. One camp holds that major terrorist groups like Al Qaeda are unlikely to undertake a chemical or biological attack even if they have basic

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[17] John Parachini, "Control Biological Weapons, but Defend Biotechnology," *Rand Review*, (Summer 2002): 34.

[18] Parachini, "Anthrax Attacks, Biological Terrorism and Preventive Responses."

[19] The lack of availability of CBW agents no longer seems to be a significant hurdle for terrorist groups with significant financial resources. Although in the post-9/11 environment the U.S. has increased restrictions and safeguards for dangerous biological agents, "beyond the United States it is frightening to note what little regulation other countries have imposed governing the transfer, storage, and use of dangerous pathogens." (Parachini, "Control Biological Weapons, but Defend Biotechnology," 35.) Many nations with highly developed CBW programs are at risk for proliferating their technology or actual agents to the highest bidders For further information on state CBW programs, see Jonathan Tucker article "The Proliferation of Chemical and Biological Weapons Materials and Technologies to State and Sub-State Actors," Center for Nonproliferation Studies, November 7, 2001, http://cns.miis.edu/research/cbw/ttuck2.htm (accessed June 4, 2007).

[20] Some analysts refer to an attack threshold at which a group becomes an established, or "legitimate," terrorist organization. Once they reach this threshold, they must maintain that level of intensity and their attacks must not fall below the established level of impact. See for example Fawaz A. Gerges, The Far Enemy: Why Jihad Went Global, Cambridge; New York: Cambridge University Press, 2005. Alice Hills also discusses escalation theory in her article, "Responding to Catastrophic Terrorism," Studies in Conflict & Terrorism, 25:4, 245 – 261. Bruce Riedel briefed Naval Postgraduate School students on Al Qaeda's escalation of tactics Bruce Riedel, Untitled Brief, Naval Postgraduate School, Monterey, CA, May 24, 2007).

[21] See discussion in Parachini, "Combating Terrorism" and Spyer's "The Al-Qa'ida Network."

capabilities to launch one, because such an attack is likely to result in lower numbers of casualties than conventional attacks and thus would actually damage their credibility.[22] The other camp argues that the economic and/or psychological impact of CBW would be significant enough to compensate for a reduced number of casualties.[23]

This debate is largely theoretical and deals with perception by terrorist groups of the significance their attacks will have to their target and the subsequent impact on their legitimacy and recruitment and fundraising efforts. There is no systematic evaluation of evidence to give more weight to the arguments of either camp. Therefore, to assess which argument is more credible, this thesis will investigate the likelihood of human casualties (both sickness and/or deaths) as well as the economic and psychological impact of a CBW attack. This can then be compared to recent terrorist attacks such as those of 9/11 to determine if such an attack would be attractive to a terrorist group like Al Qaeda, in accordance with the theory of escalation.

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[22] Proponents of this school of thought point to the Aum Shinrikyo attempts to deliver chemical and biological weapons in Japan that over a 10 year period killed 20 people and the 2001 U.S. Anthrax attacks that killed 5 people. Additionally, while the initial emotional impact was significant, recovery in both cases was quick, and most people resumed their normal routines fairly quickly. Fran Townsend, assistant to the President for Homeland Security and Counterterrorism stated "Al Qaeda will continue to attempt to conduct usually dramatic mass casualty attacks on the United States, will continue to try to acquire and employ chemical, biological, and radiological materials, and 'will not hesitate to use them." ("Kuna: Al Qaeda Still Poses Evolving Threat to U.S. Intelligence Report Concludes," Jul 17, 2007, www.intelink.sgov.gov/news (accessed August 23, 2007)). Additionally, the Apr 24, 2007 EUCOM Daily News report concluded, "They [Al-Qaeda] have got to do something soon that is radical otherwise they start losing credibility" ("Al Qaeda Planning Big British Attack," *The Sunday Times*, Apr 22, 2007, http://gidm.eucom.smil.mil:8201/DailyNews Report/2007/24Apr07 (UNCLASS) (accessed August 23, 2007)). Enemark discusses terrorist motivation of "constructing their attacks as a form of theatre," creating a "spectacular event," (Christian Enemark, "Working Paper No. 379," Canberra: National Library of Australia, October 2003). Finally, analysts at Stratfor conclude, "an attack against U.S. agriculture would lack the spectacle that Al-Qaeda prefers—not to mention that such an attack would be unlikely to cause mass chaos…[and] does not fit the conventional criteria for an Al-Qaeda Operation," ("The Unlikely Terrorist Threat Against U.S. Agriculture," Stratfor, Mar 17, 2006, http://intel.socom.smil.mil/socjic/osec (UNCLASS) (accessed August 23, 2007).

[23] See discussion in Parachini's "Combating Terrorism," Tucker's *Toxic Terror,* and Robert Pratt's "Invasive Species: The Biological Threat to America," in Howard et al, *Homeland Security.* Additionally, Barry Zellen wrote, "it only takes one successful, symbolic attack of our infrastructure to paralyze our nation, shake our confidence, and spread fear across the land…the economic consequences of a widespread attack [on U.S. agriculture] would be enormous; and the panic and fear such an attack might reap could lead to wide-scale social disruption" (Barry S. Zellen, "Preventing Armageddon II: Confronting the Specter of Agriterror," *Strategic Insights,* 3:12, Dec 2004).

D. MAJOR QUESTIONS

U.S. agricultural production and distribution are highly concentrated; therefore, they potentially pose inviting targets. However, the U.S. has procedures in place to prevent and respond to agricultural contamination. Would an attack against the nation's agriculture base be likely to create enough casualties, economic disruption, and/or fear and uncertainty to be attractive to terrorists? Is it likely that an agroterror attack would be largely contained by the systems in place? Additionally, while these response measures have been effective in recent limited natural outbreaks of contamination, would multiple attacks likely overwhelm the system?

E. METHODOLOGY

In order to assess the likely impact of an agroterror attack, and thus the attractiveness of such an attack to terrorists, this thesis will use case studies of naturally occurring biological incidents in agriculture to establish a baseline of economic impact, government response, and resulting public reaction or psychological impact. The first case study will look at the 2001 outbreak of Foot and Mouth disease in Britain and the second case study will focus on the 2006 Salinas spinach *E. coli* contamination; both cases will enable an evaluation of the effectives of government response to non-terrorist outbreaks of contamination. These cases form a valuable baseline in this evaluation, as they are documented cases in which national economies were impacted and the government's response mechanisms were put into action. The time it took to identify these incidents and isolate the contaminated products, as well as the resulting number of human casualties, economic impact of sanctions or withdrawals from commerce, and public reaction will be used as a baseline for the hypothetical scenarios for hypothetical attacks of Foot and Mouth Disease and *E. coli.* These scenarios will be used to evaluate a purposeful, planned attack against multiple areas of the U.S. agriculture sector and will enable evaluation of the likely government response to a more robust attack and the resulting ability to limit the impact of such a coordinated attack. This exercise should allow us to make a more informed judgment about the likely impact and thus the likelihood of an unconventional attack against US agriculture.

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II. 2001 FOOT AND MOUTH DISEASE OUTBREAK IN BRITAIN

A. INTRODUCTION

Foot and Mouth Disease (FMD) is the first of fifteen diseases listed on the World Organisation for Animal Health (OIE) "A List" of diseases affecting animals (see Appendix C). "A List" diseases have certain distinguishing characteristics, and FMD heads the list because it is "one of the most devastating viral animal diseases affecting cloven-hoofed animals such as cattle and swine and has occurred in most countries of the word at some point during the last century."[24] Internationally prevalent, this hardy, contagious disease is difficult to eradicate. As of 2002, approximately 60 percent of the countries in the world had reported cases of FMD (see Figure 1), prompting FMD-free countries to undertake concerted efforts to prevent FMD introduction.[25]

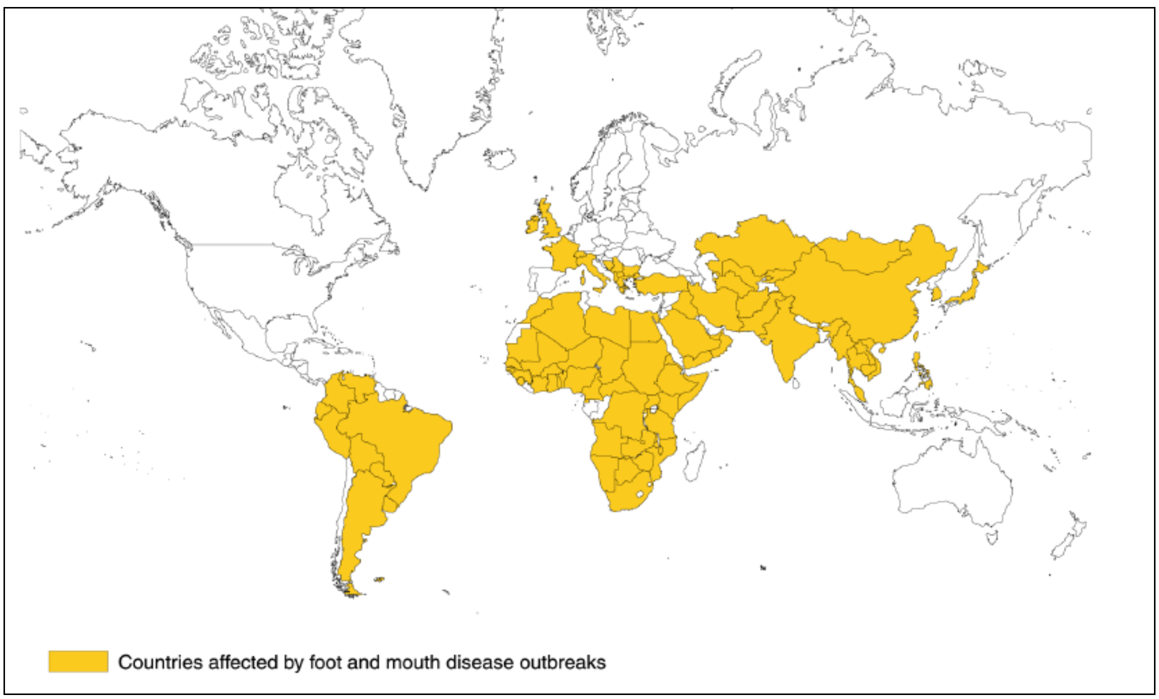

Figure 1. Worldwide Incidence of FMD, 1992 through 2002[26]

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[24] United States Government Accounting Office, "GAO-02-808; Foot and Mouth Disease; To Protect U.S. Livestock, USDA Must Remain Vigilant and Resolve Outstanding Issues," (Washington D.C.: GAO), July 2002, 12.

[25] GAO-02-808, 15.

[26] From GAO-02-808, 15.

The presence of any of the OIE "A List" diseases will lead to an immediate, complete embargo of any trade directly or indirectly linked to the infected animals.[27] Diseases on less worrisome "List B" will likely only lead to trade restrictions or additional inspections. As one of the most contagious diseases on the "A List," any FMD outbreak, however minor, could have a significant impact on a nation's economy.

This chapter will examine the threat FMD poses to the U.S., by first examining epidemiology, including prevention efforts, the detection process, epidemiology systems in place, along with response and investigation procedures. An examination of the 2001 FMD outbreak in the U.K. will facilitate an evaluation of the likely impact of a natural or intentional outbreak of FMD in the U.S. Although FMD affects all cloven hoofed animals, this chapter will deal primarily with a cattle-centric outbreak, as this represents the largest sector of the American meat industry. The cattle industry is also more concentrated, and is at greater threat of FMD infection than any other sector. An uncontrolled FMD epidemic would have widespread repercussions.

B. PREVENTION

One of the main reasons FMD is considered the most serious disease affecting livestock is its high level of contagiousness.[28] Very small amounts of the FMD virus can spread the disease, and it can be transmitted via "aerosol, direct contact, and ingestion."[29] In fact, a "few hundred microliters of scrapings from the blistered mucosa of an FMD-infected animal…can provide more than enough agent to initiate an epidemic."[30] The U.S. Department of Agriculture has primary responsibility for protecting U.S. cattle and dairy herds from diseases such as FMD, and works closely with various other federal agencies that play important roles in preventing the spread of the disease.[31] Agencies

[27] Moats, 19.

[28] Specific risk factors for contamination and spread of FMD are details beyond the scope of this thesis, but are examined in great length in Javier M. Ekboir, "Potential Impact of Foot-and-Mouth Disease in California; The Role and Contribution of Animal Health Surveillance and Monitoring Services," Agriculture Issues Center: Division of Agriculture and Natural Resources: University of California, 1999.

[29] Ekboir, 39.

[30] Mark Wheelis, Rocco Casagrande, and Laurence V. Madden, "U.S. Agriculture is Vulnerable to Bioterror Attacks." in Lisa Yount, ed., *Fighting Bioterrorism*. San Diego: Greenhaven Press, 2004, p. 32.

[31] GAO-02-808, 12.

such as the USDA's Animal and Plant Health Inspection Service (APHIS), U.S. Customs, U.S. Border Patrol, Immigration and Naturalization Service, and the U.S. Coast Guard all assist the USDA in what has become a border inspection and surveillance process. However, the effectiveness of these efforts remains debated.[32] The focus remains on detecting animal disease or preventing an already-infected animal from entering the country. To keep FMD out of the country, these agencies focus on surveillance of legal trade livestock, preventing unintentional FMD infection, and detecting intentional smuggling of unintentionally contaminated meat or animals. However, the Government Accounting Office (GAO) has concluded that the country is vulnerable to an intentional attempt to smuggle FMD.

C. EPIDEMIOLOGY

1. Detection

Although FMD rarely affects humans (largely because infected animals have been detected before entering the food distribution system), epidemiology in FMD is similar to the processes in place to detect and respond to *E. coli* in humans, which will be discussed in Chapter III. In both cases, the first line of detection is the medical provider; doctors for humans, and veterinarians for livestock. Ultimately, in accordance with the National Animal Health Emergency Response Plan (NAHERP), "detection of an animal disease is assumed to take place at the livestock owner or county extension agent level."[33]

If FMD appears in the U.S., either intentionally smuggled in or brought in unintentionally via infected animals, the focus of FMD control shifts from prevention to detection and response. However, in this area the U.S. faces hurdles as well. "Initial detection relies solely on the livestock owner/operator or local veterinarian recognizing an anomaly as potentially representing a highly contagious disease."[34] This detection occurs primarily during either three or four stages in which cows can be inspected for health. The first stage is at the farm and the second is at saleyards. For milk cows, the third and final location is milk processing plants. For beef cattle, the third stage is

[32] For further information on U.S. efforts to secure the borders from FMD, see GAO 02-808.

[33] Moats, 69.

[34] Moats, 142.

feedlots and then the fourth and final stage is in the move to slaughterhouses. In all cases, the movement of cattle across the nation is significant. This process of movement is termed agromovement, and is defined as "the continuous cycle of movement required in farm-to-fork food production, including all aspects of animal transportation, among them the movement of finished products destined for distribution and consumption throughout the world."[35]

For cattle on both farms and milk processing plants, the primary source of surveillance is the farm staff. Veterinarians serve as an auxiliary means of surveillance, but only if they are contacted by farm staff with regard to animal health concerns. Much like human infectious disease surveillance, veterinarians serve as the primary care providers and carry the responsibility of identifying, diagnosing, and treating animal infections or disease. When cattle are brought to saleyards, they are inspected by potential buyers, and "in most cases, a state livestock inspector and a brand inspector check incoming animals, and determine whether they have to be checked more closely in the slaughterhouse."[36] There are usually veterinarians on site, but it would be unusual and cost prohibitive for them to mandate inspection of all animals upon arrival.

Feedlots are large concentrations of cattle brought into consolidated locations for fattening in the final few months prior to slaughter. "More than 70 percent of the nation's cattle production is kept within a 500-mile radius on just 2 percent of the nation's feedlots. On these large 'superlots' there may be more than 250,000 head of cattle.[37] Another study estimates "the largest 30 feedlots will generate 50 percent of the finished cattle" within the U.S.[38] Similar to farms and milk processing facilities, the primary source of identification of sick animals would be accomplished by the staff or periodic veterinarian checks. However, the closest inspection of cattle in these areas is accomplished when the animals are transported from auction to the feedlot and then again when they are transported to the slaughter house. If an infected animal were identified in

[35] Terry Knowles et al, "Defining Law Enforcement's Role in Protecting American Agriculture from Agroterrorism," U.S. Department of Justice, December 2005, 110.

[36] Ekboir, 22.

[37] Moats, 8.

[38] Rocco Casagrande, "Biological Terrorism Targeted at Agriculture: The Threat to U.S. National Security," *The Nonproliferation Review,* Fall-Winter 2000, 96.

this latter transport stage, significant numbers of other animals would probably be infected as well. Slaughterhouse inspections are more stringently regulated, but thoroughness of inspections can vary. “Slaughterhouses are controlled by either federal or state inspectors to insure that they comply with technical and sanitary standards.”[39]

Some contend even trained veterinarians may not immediately recognize a non-endemic disease when they see it for the first time. In many cases, “veterinary schools have often failed to teach students how to spot early signs of foreign animal diseases.”[40] In fact, “only about 26 percent of the nation’s veterinary graduates have taken a course specifically dedicated to foreign animal diseases.”[41] Training in foreign disease identification is not required to obtain USDA accreditation – an accreditation that 80 percent of the nation’s veterinarians obtain as part of the APHIS National Veterinary Accreditation Program. While efforts by the USDA to ensure veterinarians have at least basic training in foreign diseases is ongoing, and the “USDA is working to update the Veterinary Accreditation system to emphasize continuing education,”[42] to include foreign diseases, this gap in veterinarian training presents a vulnerability in one of the first lines of disease detection. To add to the challenge, FMD can sometimes present vague or misleading symptoms, hampering quick identification of the disease. “The clinical signs of FMD are easily confused with other diseases such as vesicular stomatitis, vesicular exanthema and swine vesicular disease.”[43] These diseases are naturally occurring within the U.S., so a FMD case might be initially misdiagnosed, slowing the response, required quarantine, and subsequent traceback efforts.

2. Epidemiological Systems

As with diseases that affect humans, federal agencies have developed databases and reporting systems to facilitate rapid transference of information regarding animal

[39] Ekboir, 23.

[40] Michael A. Gips, “Protection of U.S. Agriculture Against Bioterror Attacks Has Been Strengthened,” in Lisa Yount, ed., *Fighting Bioterrorism,* San Diego: Greenhaven Press, 2004, 45.

[41] United States Government Accounting Office, “GAO-05-214; Homeland Security: Much is Being Done to Protect Agriculture from a Terrorist Attack, but Important Challenges Remain,” Washington, D.C.: GAO, March 2005, 28.

[42] GAO-05-214, 81

[43] Ekboir, 40.

diseases. The most robust of these is the National Animal Health Surveillance System (NAHSS), which "is a network of partners working together through surveillance to protected animal health. The goal of the NAHSS is to systematically collect, collate, and analyze animal health data and promptly disseminate animal health information, especially to those partners obligated to respond."[44] However, critics of the system point out its flaws, the time it takes to populate and report disease and health data. Even with NAHSS, "there is no integrated national system that can report diseases and infestations electronically in real time."[45]

A tool that can be used to assist in animal tracking and disease traceback efforts is the National Animal Identification System (NAIS), which is a voluntary State-Federal-Industry partnership designed to facilitate animal identification and tracking.[46] The concept behind NAIS is that when an infected animal is identified, this tracking would facilitate rapid tracking of the animal's origins, movements, and areas in which it would have come into contact with other animals, potentially passing its infection to other animals. However, large segments of the national beef industry (as well as others) resist tracking mechanisms because "of the costs involved and the potential for the unauthorized disclosure of proprietary information."[47] Although some members of the industry have prioritized the benefits of this system over the potential costs, large segments of the industry continue to resist, and have not enrolled in this voluntary system.

3. Response and Investigation

Response to an outbreak of FMD in the U.S. would be a critical partnership of cattle owners, veterinarians, and federal and state authorities. "A timely response [to a

[44] U.S. Department of Agriculture, "Animal Monitoring and Health Surveillance; National Animal Health Surveillance System," http://www.aphis.usda.gov/vs/nahss/nahss.htm, accessed October 23, 2007.

[45] Institute of Medicine National Research Council of the National Academies, *Countering Bioterrorism; The Role of Science and Technology,* Washington D.C.: The National Academies Press, 2002, 24.

[46] U.S. Department of Agriculture, "NAIS: At a Glance," http://animalid.aphis.usda.gov/nais/naislibrary/documents/factsheets_brochures/NAIS_AtAGlance-color.pdf (accessed October 24, 2007).

[47] GAO-02-808, 19.

FMD incident] depends on livestock producers' and private veterinarians' [sic] quickly identifying and reporting suspicious symptoms to state and federal officials."[48] As explained above, the local owners and their supporting veterinarians are the primary source for disease identification, and the entire response mechanism depends on their identification of sick animals to begin the disease identification and response process.

Once a veterinarian, owner/operator, or health official observes an anomaly, they contact the Area Veterinarian in Charge (AVIC), who is the lead federal veterinarian for the APHIS Veterinarian Services section for a designated area (usually the state). The AVIC then appoints a Foreign Area Disease Diagnostician (FADD), a certified veterinarian trained and certified in Foreign Area Diseases (FAD) by APHIS at Plum Island. The FADD will either eliminate the potential for a FAD, or forward samples to the Plum Island facility for testing and definitive identification. (Diagnostic tests for FMD require laboratory tests that are conducted exclusively in the Foreign Animal Disease Diagnostic Laboratory at Plum Island, NY.)[49] If a positive sample is obtained, state regulatory agencies move into response mode, and the suspect facility is placed under quarantine. Immediate investigation is initiated to determine the source of the FAD as well as possible cross contamination or secondary infection.[50] Further detailed actions are shown in Figure 2.

[48] GAO-02-808, 56.

[49] Ekboir, 40.

[50] The issue of cross contamination with highly contagious diseases such as FMD is significant. Moats gives numerous hypothetic scenarios of veterinarians, feed suppliers, buyers, etc. visiting numerous farms, potentially spreading the disease. Tracebacks of these movements can sometime be nearly impossible, which could lead to intense cross-contamination and spread the quarantine and eventual decontamination and herd elimination extensively.

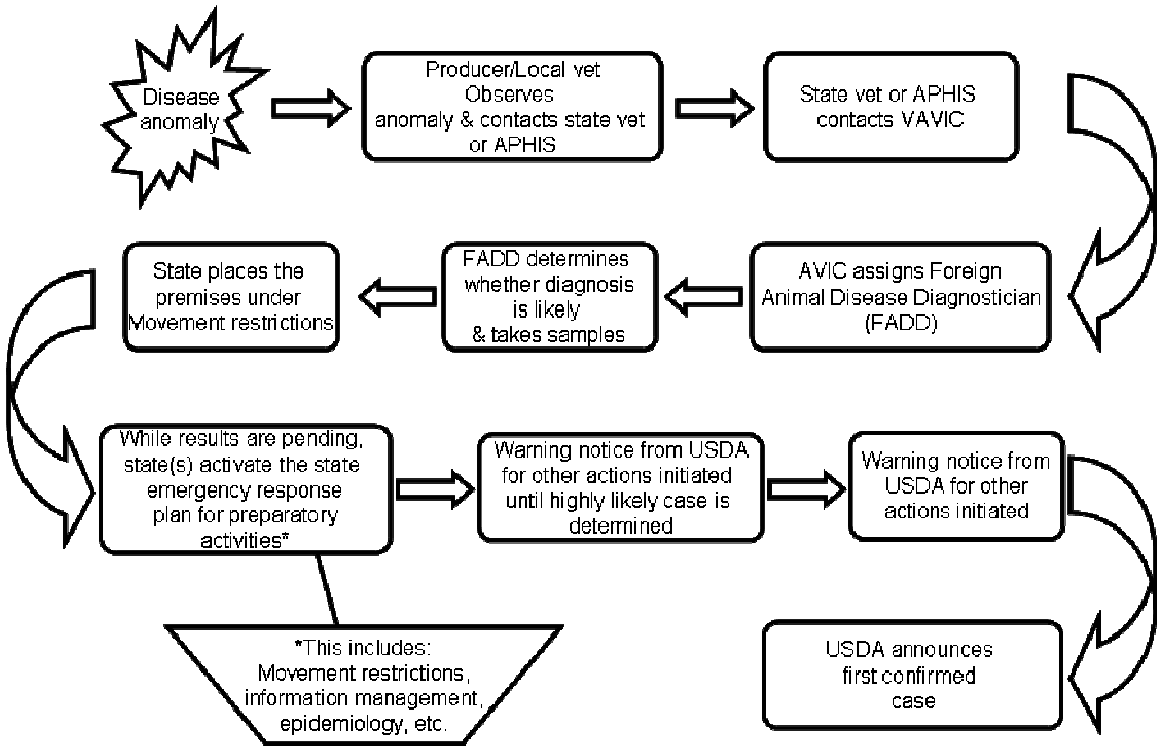

Figure 2. Initial Animal Emergency Response Process[51]

Ultimately, the goal of the response to a FMD infection is immediate response and isolation of the affected herd(s). Once isolated, quarantine, control and recovery operations can commence, but without containment the disease can continue to spread. As will be discussed below, the initial response and containment in the U.K. to the FMD outbreak in 2001 was too slow to prevent widespread infection, leading to a national FMD outbreak. The U.S. faces many challenges in this area as well. As discussed above, there are several stages during which an infected cow can be identified; however, traceback investigation will be extremely difficult due to the significant agromovement of cattle, as well as the close interaction of staff and veterinarian personnel. By the time an infected cow is identified, it may have moved numerous times and been in contact with countless others. To compound this already difficult problem, trucks used to transport infected cows, feed, or by-products may have come into contact with other farms, auction

[51] From Moats, 143.

yards, or feedlots. FMD is so contagious that even coincidental contact could cause infection and a contaminated vehicle could contribute to the spread of the disease.

If the preventive efforts of the nation fail and an epidemic breaks out, the national response plan calls for nothing less than disease eradication. This "stamping-out" response entails the "slaughter and burning or burial of all infected and exposed (even though asymptomatic) susceptible animals in the quarantine area, followed by clearing and disinfection of exposed premises."[52] There are numerous issues associated with the large scale culling that would be required, ranging from pure mechanics that include the logistics of killing the vast numbers required, disposal mechanisms (burial versus burning) to the psychological impact, and how farmers, their families, and the general public would respond to large mass graves or huge disposal pyres that fill the air with acrid smoke. Additionally, the resources for identification of FAD are limited and could easily be overwhelmed by samples during even a single outbreak.

The 2001 U.K. FMD outbreak illustrates many of the concerns described above. Britain has a similar mechanism of detection and response, relying upon the owners and local veterinarians to detect the first signs of contagious disease. By examining the outbreak that occurred, and the associated response mechanisms, this case study will help model a potential outbreak of FMD in the U.S., enabling an assessment of the likely impact of such an incident.

D. CASE STUDY

1. Reporting

The first case of Foot and Mouth Disease in 2001 was reported from infected sows in Essex County on February 19th.[53] As with most FMD outbreaks, "the first case [was] detected and reported by a veterinary surgeon." [54] Once the first case was reported,

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52 Ekboir, 39.

53 Paul R. Hunter et al, "Foot and Mouth Disease and Cryptosporidiosis: Possible Interaction between Two Emerging Infectious Diseases," Center for Disease Control; Emerging Infectious Diseases, January 2003, http://www.cdc.gov/ncidod/eid/vol9no1/02-0265.htm (accessed October 31, 2007).

54 Department of Environment, Food, and Rural Affairs (DEFRA), "Origin of the U.K. Foot and Mouth Disease Epidemic in 2001," http://www.defra.gov.uk/footandmouth/pdf/fmdorigins1.pdf (accessed October 30, 2007), 11.

response and investigation began, and the speed with which the British government responded to this first case is noteworthy. According to John H. Kirk, Extension Veterinarian at the University of California at Davis School of Veterinary Medicine, "Within 5 hours of observing classic signs of FMD, a livestock movement ban was placed in a 10-mile zone around the area."[55]

While the first case was identified in Essex County, investigation would indicate that the original FMD case in Britain was actually a "pig finishing unit" at Burnside Farm, Northumberland. From this first (or index) case, FMD appears to have spread via two main avenues. First, the sows that were transported to Essex County (where they became the first reported cases of FMD) and infected other pigs at the facility there. Second, and more dramatic, there was an airborne transmission of FMD from pigs on Burnside Farm to sheep and cattle on farms in close proximity. The infected sheep were then sold through local markets and dealers and spread FMD quickly throughout England, Wales and southern Scotland.[56]

2. Response

After the first case of FMD was identified, the government employed movement restrictions. However, as explained above, the first cases identified were not actually the first cases of the disease in the country. By the time these movement restrictions were emplaced, the disease was already outside the initial containment areas. "The scale of the FMD outbreak was greater, and moved much faster, than anticipated. It escaped from 'zones of control' and appeared in different regions of the country months after the initial disease outbreak."[57] Compounding this was the delay "between the introduction of infection and the reporting of suspect disease to the authorities. This contributed to the widespread dissemination of disease and the scale of the epidemic."[58]

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55 John H. Kirk, "Foot-and-mouth disease in the UK - What can we learn? Are we prepared?" http://news.ucanr.org/newsstorymain.cfm?story=442 (accessed October 31, 2007).

56 DEFRA, "Origin of the U.K. FMD Epidemic," 4.

57 CAPT Stephanie R. Ostrowski,. DVM, MPVM, Diplomate ACVPM, "The Emergency Response to Foot and Mouth Disease in England," *Commissioned Corps Bulletin*, XV:11, (November 2001).

58 DEFRA, "Origin of the U.K. FMD Epidemic," 7.

To prevent the continued spread of FMD throughout the U.K., the Department of Environment, Food, and Rural Affairs implemented a robust disease control strategy (see Figure 3). This strategy was built upon a series of movement control procedures. First, Protection Zones were established in a three kilometers radius from infected farms.

The main elements of the disease control strategy

1. Controlling movements of susceptible animals
2. Maintaining a high level of biosecurity to prevent spread by persons and vehicles that had contact with an infected premises
3. Rapid reporting, identification and diagnosis of infected animals
4. Swift tracing of animals which had been exposed to infection
5. Rapid slaughter of susceptible animals on infected premises or that had been exposed to disease
6. Disposal of carcasses
7. Preliminary and secondary cleansing and disinfecting of premises
8. Statistically based serological testing of animals for evidence of current or previous disease to enable restrictions to be lifted safely

Figure 3. The main elements of the U.K. disease control strategy[59]

Additionally, a Surveillance Zone of 10 kilometers radius was extended beyond that. Finally, a national movement ban "affecting cattle, sheep, pigs and other ruminants" was imposed throughout England, Scotland, and Wales. No movement of susceptible animals was allowed without special permission and restrictions.[60] Additionally, controls were implemented on the movement of "animal carcasses and animal gatherings."[61] Biosecurity measures were also implemented; "in the Protection and Surveillance Zones, there [were] requirements for increased levels of biosecurity on farms, movement controls, controls on transportation of dung/manure and treatment of animal products to ensure destruction of the Foot and Mouth Disease virus."[62]

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[59] From National Audit Office, "The 2001 Outbreak of Foot and Mouth Disease," 21 June 2002, http://www.nao.org.uk/publications/nao_reports/01-02/0102939.pdf (accessed October 31, 2007), 55.

[60] DEFRA, "Foot and Mouth Disease Confirmed in Surrey: National Movement Ban in Place," http://www.defra.gov.uk/news/latest/2007/animal-0912.htm (accessed October 31, 2007).

[61] DEFRA, "FMD Confirmed in Surrey."

[62] Ibid.

It is critical when evaluating this epidemic to note that although the sows in Essex County were the first animals to be diagnosed with FMD in the U.K. in 2001, by the time they were identified as sick, the pigs at Burnside Farms had already infected nearby sheep and cattle, which were entering the commerce chain and spreading the disease throughout the U.K. Later investigation would conclude that the pigs at Burnside Farms were likely infected as early as late January or early February 2001, and that a single case of FMD initiated the national epidemic. In fact, at least 57 farms were infected by the time the first outbreak was confirmed on February 20th, and at least 119 farms had been infected by the time national movement controls were implemented on February 23.[63] As shown in Figure 4, by the end of April 2001 the majority of cases had been reported; however, containment of the disease was incomplete and the epidemic lasted until the end of September. In all, a total of 2,030 cases of FMD in Britain were confirmed during this epidemic.[64]

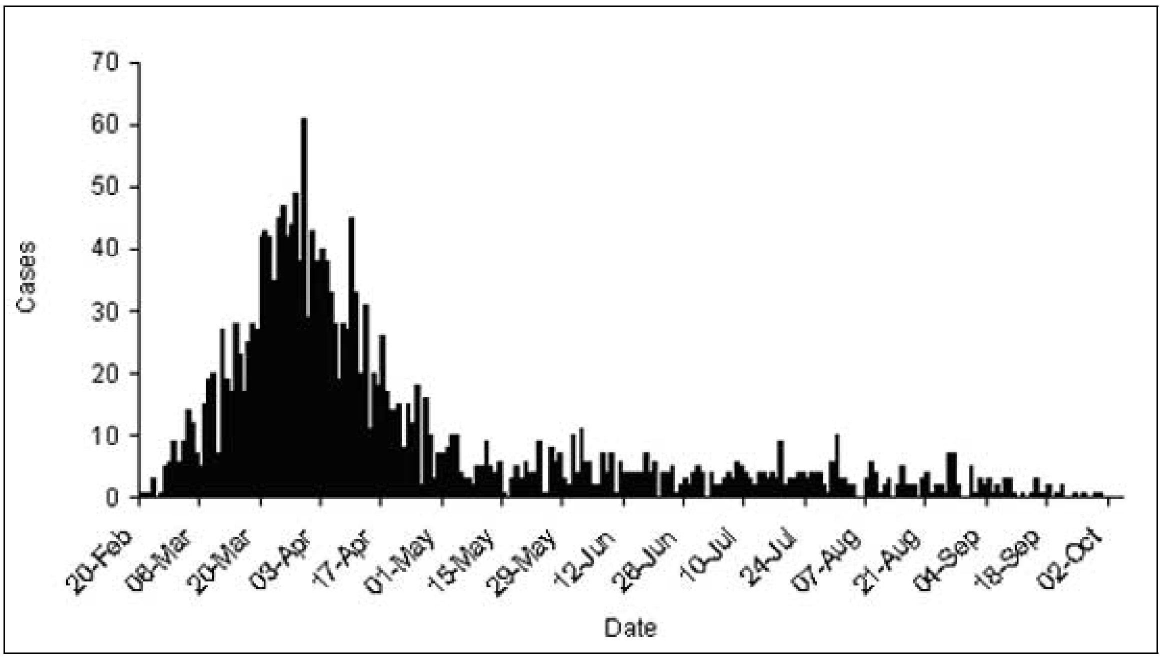

Figure 4. Epidemic curve of the 2001 U.K. FMD outbreak.[65]

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[63] DEFRA, “Origin of the U.K. FMD Epidemic,” 9.

[64] Hunter et al.

[65] From Ibid.

As a result of the national FMD epidemic, the U.K. imposed a national ban on the export (and most other nations imposed national bans on the import) of all potentially affected meat (port, mutton, beef) as well as associated products that could be infected or carry the disease (milk, wool, leather, and other secondary animal products). As will be shown below, these restrictions had a dramatic impact on the U.K. economy.

Once national movement controls were established, the government began the process of containment and eradication. Authorities pursued containment through implementation of the control zones discussed above. The eradication efforts entailed mass slaughter of animals, both infected and exposed, and either mass burial or incineration. Disposal methods are depicted in Figure 5. "Over 4 million animals were slaughtered during the U.K. outbreak to control the disease,"[66] and both direct and indirect costs were significant.

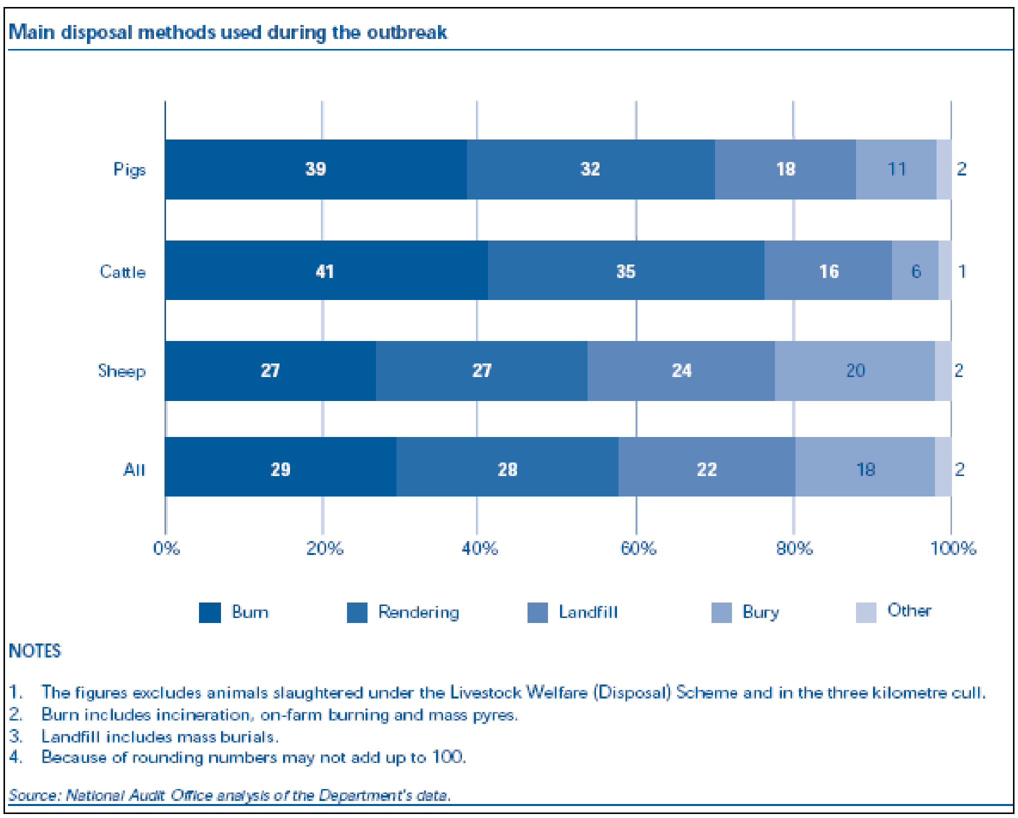

Figure 5. Main disposal methods used during the outbreak.[67]

66 GAO-02-808, 20.

67 From National Audit Office, 72.

3. Investigation

Investigation and response began immediately after the first case of FMD was identified, but the process was slowed by the fact that the first case identified was not actually the original case of infection in the U.K. By the time response began, the disease had begun to spread. Once the index case was identified as swine on Burnside Farm, the investigation was able to focus on the potential origination of FMD. Investigators examined different transmission routes for FMD introduction to the U.K., considering transmission by animals, people, vehicles, equipment, vermin, and wildlife.[68] However, none of these transmission routes appeared viable. Investigators also considered the possibility that FMD was already present within the U.K. and the potential that the epidemic resulted from its release. However, after considering the many alternatives, the investigators concluded, "the likeliest source of infection for the pigs on Burnside Farm was meat or meat products containing or contaminated with FMD virus and that the virus could have been introduced to the pigs through the consumption of such material in unprocessed or inadequately processed waste food or the consumption of the processed waste food contaminated with such material." [69]

4. Attribution

Investigators never definitively determined the cause of the 2001 FMD epidemic in the U.K. The official report on the outbreak concludes: "It will never be possible to determine the exact route by which the virus entered the country."[70] Investigators believe the FMD was most likely introduced via contaminated meat or meat products that were then fed to the pigs at Burnside Farm, but although genetic analysis of the U.K. FMD linked it with other outbreaks in Europe and South Africa, further evaluation suggested the virus originated in the Far East and was brought to the U.K. in contaminated meat or meat products, introduced unintentionally from a contaminated source.[71]

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[68] DEFRA, "Origin of the U.K. FMD Epidemic," 3.

[69] DEFRA, "Origin of the U.K. FMD Epidemic," 3.

[70] Ibid., 5.

[71] Ibid., 4.

5. Financial Impact

The 2001 FMD outbreak in the U.K. was devastating to several sectors of the British economy as a result of significant direct and indirect costs. Direct costs include costs of isolation, eradication, decontamination, destruction and disposal of infected animals, as well as loss in revenue created by both domestic sales and exports. According to U.K. government estimates, "the direct costs for control and eradication of the 2001 outbreak was [sic] about $4 billion."[72] The impact on the export markets alone cost the U.K. at least $2.4 billion.[73] Indirect costs are more difficult to measure because these costs deal with ancillary costs affecting consumers, including unemployment caused by direct and affiliated industries and decreased consumption of cattle-related industries. As an example of indirect costs, analysts estimated lost tourism revenue cost the nation $5 billion, a figure alone higher than the direct costs for eradication of the disease, and a nearly 12 percent drop in national tourism revenue.[74]

Another impact of a national epidemic that is more difficult to measure is consumer confidence. This confidence can be in the food supply available as well as the population's confidence in the ability of their government to respond and contain an incident affecting the nation. "A survey by the United Kingdom's Institute of Grocery Distribution determined that because of the FMD and mad cow disease outbreaks, many consumers in the United Kingdom now consider meat and dairy products to be unsafe."[75]

This concern can have long term impacts on the economy that can be felt for years after the direct and indirect costs of the incident itself. For example, it was not until 2004 that tourism earnings reached the 2000 level. Additionally, livestock production

[72] GAO-02-808, 19.

[73] Peter Chalk, "Untitled Paper," Conference Proceedings; Threat Panel: The Threat Beyond 2000," RAND, http://www.rand.org/nsrd/bioterr/chalk.htm (accessed October 9, 2007), 7.

[74] GAO-02-808, 20; Office for National Statistics, "MQ6: Transport Travel and Tourism: Quarter 4 2002," http://www.statistics.gov.uk/downloads/theme_transport/MQ6_Q4_2002.pdf (accessed November 14, 2007).

[75] GAO-02-808, 21.

also took several years to recover; and to date, the pig revenue has not fully recovered, and as of 2006 represented only 85 percent of pre-2001 pork contributions to U.K. GDP (see Figure 6).[76]

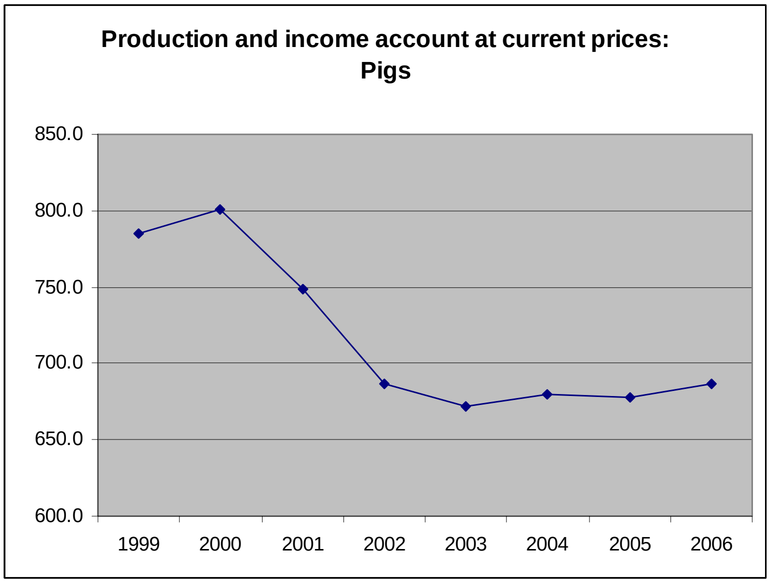

Figure 6. U.K. Pig Output, 1999-2006.[77]

The economic impact of the 2001 FMD epidemic appears significant, and while direct costs are estimated at $6.4 billion, indirect costs are harder to estimate. Overall economic impact assessment of the FMD epidemic is unavailable, but there are certainly other sectors of the economy not included in the figures above. However, with a national GDP of U.S. $1.4 trillion in 2001, the impact of $11.4 billion represents only a small percentage.[78]. While specific sectors of the economy were certainly severely affected, the nation did not suffer significant economic impact as a whole. In fact, it is now

[76] DEFRA, "Agricultural Quick Statistics," http://statistics.defra.gov.uk/esg/publications/auk/2006/table9-1.xls (accessed November 14, 2007).

[77] From DEFRA, "Agriculture in the United Kingdom," http://statistics.defra.gov.uk/esg/publications/auk/2006/ (accessed November 14, 2007).

[78] "The Economy: Economic Structure," Economist Intelligence Unit (EIU) Country Profile Select: March 1, 2003.

estimated that the U.K. GDP continued to increase after the FMD epidemic. U.K. GDP increased 2.1 percent in 2002, 2.7 percent in 2003 and 3.3 percent in 2004.[79]

6. Analysis

This case highlights the greatest concern with an outbreak of FMD: its high degree of contagion. This case shows that once a case of FMD is detected a country may take swift action and immediately emplace control measures and still find that these actions are too late to prevent a national outbreak. Even when quarantine and movement control measures are implemented immediately after the first identification of FMD, as they were in the U.K. case, the first diagnosed case may not be the index case, and in any case given the highly contagious nature of FMD the index case may already have infected numerous other animals. Additionally, this case shows that the economic impact of eradication efforts themselves may be a small fraction of the overall economic impact, which includes loss of consumer confidence and loss of revenue from other sectors reliance upon cattle, sheep, and swine.

E. COUNTERFACTUAL U.S. CASE

1. The U.S. at Risk

Like many countries with robust livestock populations, the U.S. is at risk of a FMD epidemic. Whether accidentally or deliberately introduced into the country, the results would be widespread. Either path of infection would likely spread quickly, infecting cattle, swine, and sheep, and necessitate herd isolation and, in many cases, destruction. The following section will examine U.S. susceptibility of FMD epidemic, and the economic impact of such an event.

Agriculture accounts for 13 percent of the U.S. GDP and 18 percent of domestic employment.[80] As part of this robust agricultural sector, the U.S. has a significant reliance upon cattle, sheep, and swine. Therefore, the U.S. is very vulnerable to a FMD epidemic. Projections also suggest that a FMD epidemic in the U.S. would have a

[79] Rhys Blakely, "GDP Figures Since 2001 Revised Higher," *Times Online*, June 30, 2006, http://business.timesonline.co.uk/tol/business/economics/article681403.ece (accessed December 1, 2007).

[80] GAO-05-214, 10.

significant economic impact. The U.S. produces 26 billion pounds of beef and 22 billion pounds of pork, and a FMD outbreak would halt production of beef, pork and sheep in the affected regions until the outbreak could be contained.[81] According to a USDA study, an outbreak in the United States comparable to the one in the U.K. would require the destruction of about 13 million animals.[82] This represents approximately 13.4 percent of the nation's 2006 cattle herd.[83] By comparison, the U.K. epidemic led to the culling of 4 million animals, representing nearly 36 percent of the U.K. cattle.[84]

U.S. vulnerability to a FMD epidemic has grown significantly in recent years, as a result of changes in the average size and concentration of the nation's herds. Farms continue to get larger and more concentrated, with the overall number of farms decreasing (see Figure 7 and Figure 8). This is especially pronounced in cattle production. In 2000, just "2 percent of the nation's feedlots suppl[ied] three quarters of its cattle."[85] The USDA reports a 73 percent reduction in the number of farms between 1935 and 1997, with large farms (categorized as farms greater than 500 acres) increasing to nearly 20 percent of the total number.[86] The U.K. experienced a similar change in farm structure; between 1967 and 1999, sheep and cattle holdings per farm approximately doubled.[87] As of 2005, 2 percent of the nation's feedlots produced more than 70 percent of grain-fed beef cattle production and 5 percent of the nation's feedlots accounted for 80 - 90 percent.[88] Larger farms have evolved as a more efficient means for livestock production, but this concentration also increases vulnerability to epidemics. As a result,

[81] U.S. Department of Agriculture, "Agriculture and Food; Critical Infrastructure and Key Resources Sector-Specific Plan as input to the national Infrastructure Protection Plan," May 2007, 47.

[82] GAO-02-808, 20.

[83] U.S. Department of Agriculture, "Quick Stats U.S. & All States Data - Cattle & Calves" http://www.nass.usda.gov/QuickStats/PullData_US.jsp (accessed November 15, 2007).

[84] DEFRA, "Cattle and calves; beef and veal; United Kingdom," http://statistics.defra.gov.uk/esg/publications/auk/2005/5-13.xls (accessed November 15, 2007).

[85] Anne Kohnen, "Responding to the Threat of Agroterrorism: Specific Recommendations for the United States Department of Agriculture," (BCSIA Discussion Paper 2000-29, John F. Kennedy School of Government, Harvard University, October 2000, 22).

[86] U.S. Department of Agriculture, *The Agriculture Factbook 2001-2002*, http://www.usda.gov/factbook/chapter3.pdf, (accessed November 15, 2007), 25.

[87] DEFRA, "Comparisons with 1967: Average number of livestock per holding in 1967 and 1999" http://www.defra.gov.uk/FootandMouth/2001/chart4.htm (accessed November 15, 2007).

[88] GAO-05-214, 1; 8.

“deliberate introduction of a highly contagious animal disease in a single feedlot could have serious economic consequences.”[89]

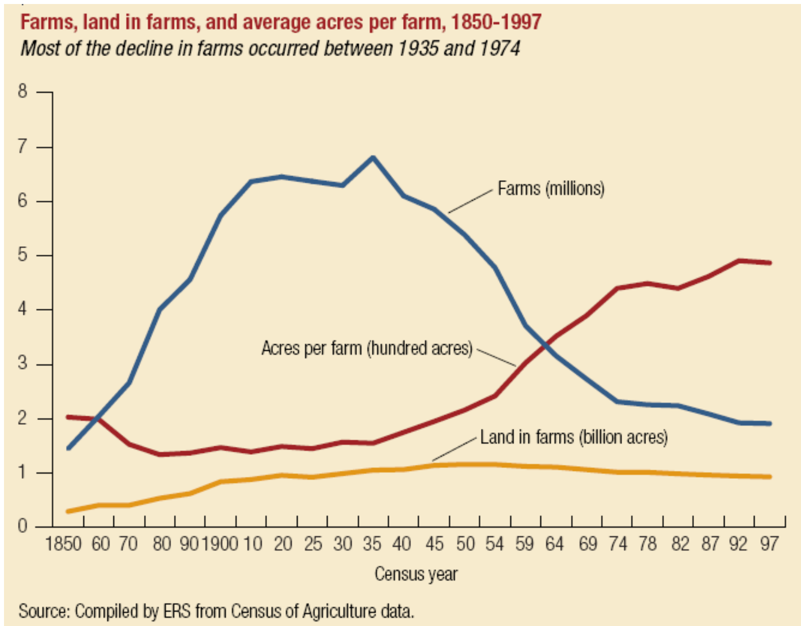

Figure 7. Farms, land in farms, and average acres per farm, 1850-1997[90]

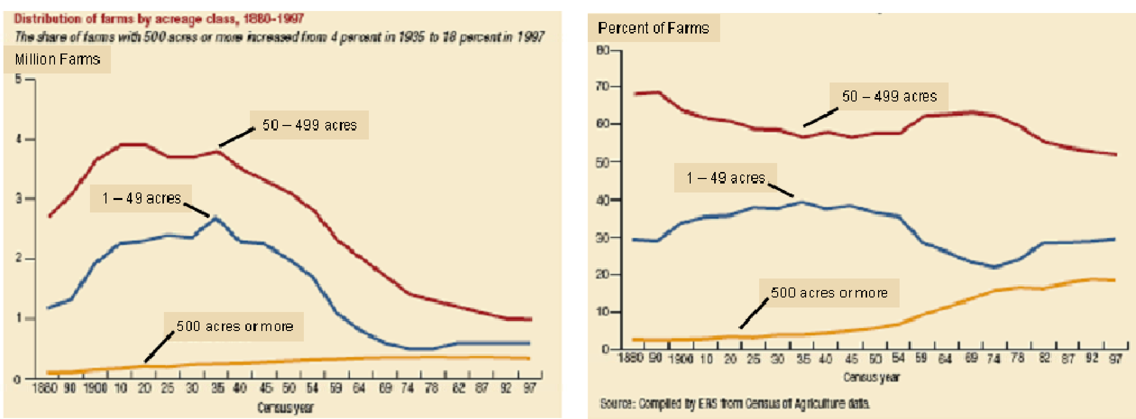

Figure 8. Distribution of farms by acreage class, 1880-1997[91]

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[89] GAO-05-214, 1.

[90] From USDA, *The Agriculture Factbook 2001-2002*, 24.

[91] From Ibid., 25.

2. Outbreak

If FMD were introduced into the U.S. cattle, pork, or sheep feedlots, it would spread quickly. If the disease were not immediately identified and contained, it would likely spread throughout the nation and completely shut down domestic consumption and foreign export of all beef, pork, and sheep, along with associated products. "Some experts believe that the virus could travel more than 175 miles on wind currents."[92] The ease with which FMD can spread is compounded by farm concentration. In fact, some experts believe an infectious disease such as FMD "could spread to as many as 25 states in as little as five days, simply through the regulated movement of animals between farm and market."[93] Without immediate containment, this spread would likely create a national epidemic like the 2001 case in Britain.

Because of its high level of contagion, FMD could easily be introduced into the U.S. by a terrorist group. Since "only small amounts are needed, they can be easily smuggled into the country with essentially no chance of detection."[94] A sample of the virus could be collected from an infected animal in another country and be smuggled into the U.S. and used to begin large scale contamination. In fact, only "a few hundred microliters of scrapings from the blistered mucosa of an FMD-infected animal…can provide more than enough agent to initiate an epidemic."[95] Samples could be collected f and easily transported to the U.S. simply by smearing the virus on a rag. The contamination could then be initiated at any of the sites discussed above, and the spread of the disease would likely be immediate and far-reaching, with tremendous consequence.

Because FMD is a naturally-occurring virus it can appear anywhere in the world. Previously FMD-free nations have witnessed its introduction and often the source of the virus is never determined (like the U.K. in 2001). If FMD appeared in the U.S., the investigation might end with the same probable hypotheses as the U.K., and assumption

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92 Moats, 19.

93 Chalk, 4.

94 Wheelis, et al., 32.

95 Ibid.

that the virus was introduced by accident. Therefore, even if a terrorist group introduced FMD into the U.S. and started an epidemic, it might remain un-attributed indefinitely. Only if the group claimed responsibility or authorities found evidence tying the epidemic to intentional contamination could attribution occur.

3. Financial Impact

A FMD epidemic in the U.S. would have impact on numerous sectors of the U.S. economy. This remains true whether the epidemic was initiated intentionally or the virus was introduced accidentally (as the investigators concluded in the U.K.). The GAO and other agencies have evaluated the potential financial impact of a FMD epidemic in the U.S. GAO Report GAO-02-808 concludes the direct and indirect costs of an outbreak would be significant. In 2006 the U.S. produced 70.7 billion pounds of meat animals (cattle, sheep, and swine), and had $41 billion in beef sales, $19 billion in dairy sales, and $14 in pork sales.[96] As an OIE List A disease, FMD would lead to an immediate halt in the sale of all of these products and immediate loss of revenues.

Direct costs of an outbreak are fairly easily measured and quantified. According to the GAO estimate, a FMD epidemic in the U.S. would lead to direct cost for eradication of approximately $24 billion.[97] Additionally, the loss of export sales would cost the U.S. economy between $6 and $10 billion a year "while the United States eradicated the disease and until it regained disease-free status."[98] This loss in export sales represents approximately 8.7 – 14.6 percent of the U.S. agricultural exports in 2006.[99] Estimates vary, but range from 5 to 10 years before a nation's exports fully recover from an epidemic, and trade resumes normally.

Indirect costs are more difficult to quantify, and therefore more difficult to estimate for a hypothetical epidemic scenario. A national FMD epidemic would likely

[96] Wheelis, et al., 29; USDA, "Quick Stats U.S. & All States Data – Livestock, Production and Income," http://www.nass.usda.gov/QuickStats/PullData_US.jsp (accessed November 15, 2007).

[97] GAO-02-808, 20.

[98] GAO-02-808, 20.

[99] The USDA reports Agricultural exports of $68.7 billion for 2006, estimating $79.0 billion for 2007. (USDA, "Agricultural Outlook tables published October 2007," http://www.ers.usda.gov/publications/agoutlook/aotables/2007/10Oct/Ao1007.pdf (accessed November 15, 2007)).

lead to "unemployment, loss of income…and decreased economic activity, which could ripple through other sectors of the economy as well."[100] Although the GAO and others have examined the many sectors that would be impacted by such an event, an accurate estimate of this ripple effect has not been accomplished. Certainly a FMD outbreak would not only impact the industries producing beef, port, and mutton, but also the industries that support that production: meat-processing facilities, feed suppliers, etc.[101] However, livestock exports represents only a small percentage of the U.S. robust, diverse economy (GDP estimated at $13.16 trillion and total exports estimated at $1.023 trillion in 2006), and while other sectors of the economy would also be impacted,, a FMD epidemic in the U.S. is unlikely to shake the economic foundation of the nation. [102]

4. Psychological Impact

Although the economic impact of a FMD outbreak is relatively easy to measure, and even to estimate, an even more important measurement is the public's reaction and loss in confidence as a result. This loss of confidence could be in the safety of the food supply, confidence in the cattle, sheep and swine industries' ability to safeguard their herds and identify illness in their animals, and in the government's ability to respond quickly and effectively to contain and eradicate the disease. Finally, this loss in confidence likely extends to the international community's judgment of the safety of the affected country's exports. If the epidemic were attributed to terrorists, or a group claimed responsibility, the psychological impact of the outbreak would be even more substantial.

In the U.K. FMD epidemic, the psychological impacts were significant. Those directly affected by the outbreak experienced symptoms including "tearfulness, lack of sleep, loss of appetite, increased anger irritability, … general depression…[and] an

[100] GAO -02-808, 20.

[101] Peter Chalk suggests that even if a limited central prairie province outbreak of FMD could be immediately contained and further infection prevented, and eradication costs for even an isolated outbreak were as low as $2 million, with "the ramifications of international embargoes, canceled overseas purchasing contracts and reduced international consumer demand…the true cost of the epidemic [could reach] U.S. $2 billion" (Chalk, 8). While this 1:1,000 ratio cannot hold true to a nation-wide epidemic, it highlights the possible second and third order affects of an epidemic.

[102] Central Intelligence Agency, "The World Factbook," https://www.cia.gov/library/publications/the-world-factbook/geos/us.html (accessed November 15, 2007).

increase in marital discord."[103] The general public was also affected by the reduced availability of food products, confidence in the food supply, and witnessing eradication efforts throughout the country. Although the British government took pains to minimize the impact, the public was exposed to huge funeral pyres and mountains of animal carcasses awaiting disposal.

In the U.S., the psychological impact would likely be similar. Those directly employed or involved with the livestock sector would face the same stressors as their British counterparts. The general public would also be faced with reduced meat products and concerns with safety of the food supply. If investigation led to the conclusion the epidemic was accidental, attention might focus on improving detection and response actions. However, if the epidemic was attributed to intentional contamination, the public would likely lose confidence in the safety of the national food supply, and more importantly, the ability of the U.S. government to safeguard a major sector of the nation. The sight of piles of carcasses, mass burials, and huge funeral pyres would highlight U.S. vulnerabilities to terrorist attack.

F. CONCLUSION

This chapter examined FMD and the U.S. focus on prevention and detection, and then response and investigation. The U.K. FMD case study serves to highlight the vulnerability of livestock to FMD, and how even an unintentional introduction of the disease can rapidly spread and cause destruction of the nation's herds. Additionally, the case study shows the importance of immediate isolation and response, and the severity of repercussions of failing to establish immediate containment. U.S. and U.K. capabilities to detect FMD are similar, and the 2001 FMD epidemic in the U.K. clearly shows any delays in containment of FMD can be catastrophic. Although the U.S. has systems in place to identify FMD, they are likely to be ineffective in preventing a nation-wide epidemic.

A U.S. outbreak of FMD (either accidental or intentional) would cause damage to the economy reaching billions of dollars. Long term impacts would also be significant as

[103] GAO-02-808, 21.

the world placed embargos on American products. Trade deficits would create ripple effects in other sectors of the economy, and while remaining a fraction of the GDP, are not insignificant, especially in the livestock and associated support sectors of the economy. While the psychological repercussions of a FMD attack would impact both the American public and the international community, the number of human casualties would most likely remain negligible.

The U.S. detection and response systems are likely to act too slowly to contain a nation-wide FMD epidemic. As in the U.K. case, by the time the first infection is detected, the virus could have already spread undetected. If the U.S. detection and response systems are likely to fail in preventing a nation-wide FMD epidemic, how then, can one measure a terrorist's motivations to conduct an agroterror attack using FMD and how would the impact of such an attack would be viewed in the context of escalation? This chapter has laid the foundation on which the answers to these questions will be addressed in Chapter IV.

III. 2006 SALINAS ESCHERICHIA COLI (*E. COLI)* SPINACH OUTBREAK

A. INTRODUCTION

In September 2006, a nation-wide *E. coli* outbreak that would cause nearly 200 people to fall ill and kill at least three was identified. Investigation would link the *E. coli* to contaminated spinach originating from the Salinas Valley region of California. This contamination would have a direct economic impact on the region and lead to a nation-wide decrease in consumer confidence in the safety of the nation's spinach and bagged salad. As soon as the contamination was identified, national response mechanisms were put into place, an investigation initiated, and efforts to mitigate the impact were begun.[104]

This chapter will examine the U.S. identification and response to food-borne contamination using the Salinas *E. coli* outbreak to evaluate the timeliness and overall effectiveness of the process. An examination of U.S. epidemiology, the process by which a food-borne contamination and resulting human illness is identified, will enable a clear understanding of the mechanisms used to identify food-borne illnesses. Next, the Salinas case study will highlight how federal and state agencies respond to outbreaks of food contamination to minimize further illness, locate and isolate the source, and work to reassure the public on the safety of their food. Next, the financial impact of this naturally occurring outbreak will be assessed to facilitate counter-factual case development for a multi-crop terror attack using *E. coli*.

[104] For a comprehensive analysis of the outbreak and resulting investigation, refer to California Department of Health Services and U.S. Food and Drug Administration, "Investigation of an Escherichia coli O157:H7 Outbreak Associated with Dole Pre-Packaged Spinach," March 21, 2007, http://www.dhs.ca.gov/ps/fdb/local/PDF (accessed September 19, 2007).

B. EPIDEMIOLOGY

"Speed of detection depends on successful medical surveillance."[105]

1. Detection

Epidemiology refers to the preventive processes in place in a community to detect, identify, and respond to illness or disease. It becomes an integral component of biological terrorism response, because illnesses may appear and begin to spread well before it becomes known that they are caused by anything other than natural causes. Whether naturally occurring, or as a result of covert terrorist attack, people with symptoms of an illness will traditionally present themselves to either their doctor or an emergency room for treatment.[106] Because even people in the same community will likely have different doctors or be seen in different hospitals, a system is in place to ensure individual cases can be aggregated to show larger trends of illness in a single location or across the nation. An additional complication is the initial ambiguity of symptoms that may be presented; covert biological attacks would most likely mimic natural illness.[107] After initial diagnosis, reporting and coordination from the local to the national level becomes a complex matrix of agencies and responsibilities (see Figure 9).

[105] Brain Bernett, "U.S. Biodefense and Homeland Security: Toward Detection and Attribution," (Master's Thesis, Naval Postgraduate School, December 2006), 65.

[106] "AIMA Recommendations for National Health Threat Surveillance and Response," *Journal of the American Medical Information Association,* 9:2 (Mar/Apr 2002), 204.

[107] Jennifer Brennan Braden, MD, MPH, "Preparing for and Responding to Bioterrorism; Information for the Public Health Workforce," University of Washington Northwest Center for Public Health Practices, www.nwcphp.org/training/courses-exercises/courses/bttrain-phw/ (accessed October 15, 2007).

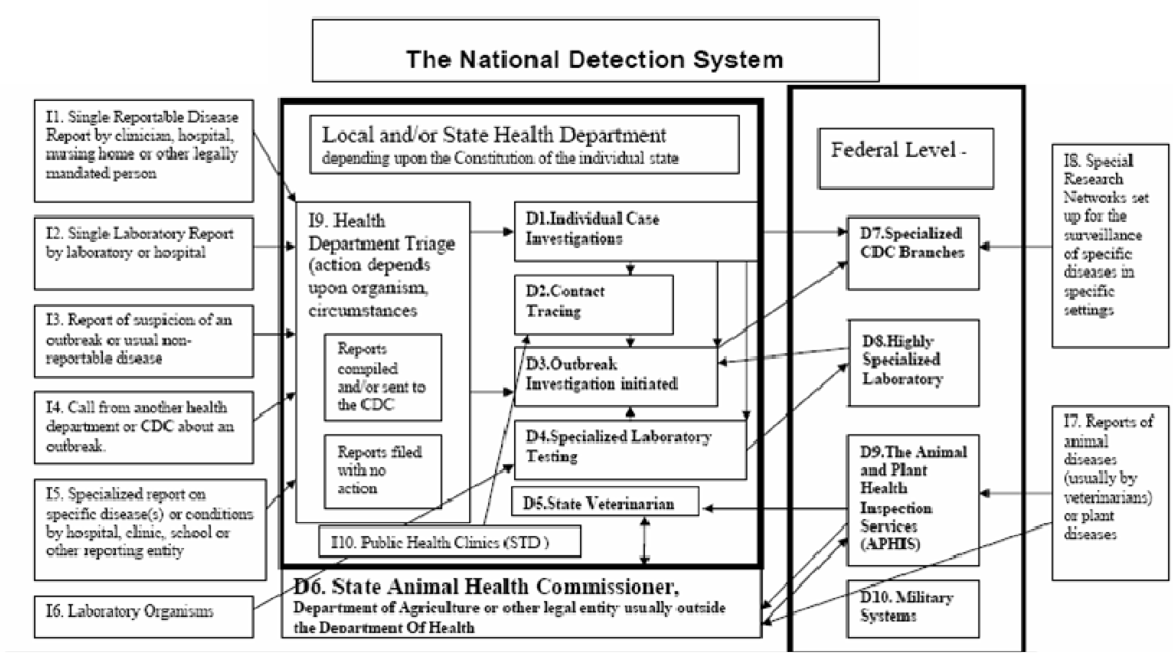

Figure 9. The National Detection System.[108]

Although the U.S. Centers for Disease Control (CDC) bears overall responsibility for tracking disease or illness outbreaks throughout the country, without detailed reporting from communities across the country, this difficult task would be truly impossible. To make a diagnosis, “a patient must seek medical attention, the physician must decide to order diagnostic tests, and the laboratory must use the appropriate procedures.”[109] Once the physician makes a reportable diagnosis, the illness is reported to local and state health departments who coordinate with the CDC. The CDC acts in concert with all the state health departments to collect surveillance information on food-borne illnesses to determine if there are disease outbreaks.

In identifying a widespread outbreak of illness, whether caused naturally or by covert terrorist attack, clinics, doctors, and emergency rooms are given guidance on what

[108] From Michael M. Wagner et al., “The Nation's Current Capacity for the Early Detection of Public Health Threats Including Bioterrorism,” (Rockville, MD: Agency for Healthcare Research and Quality, September 26, 2001), v, http://rods.health.pitt.edu/LIBRARY/dato1AHRQInterimRpt112601.pdf (accessed October 15, 2007), 25.

[109] Lonnie King, “Testimony Before the Committee on Health, Education, Labor and Pensions, United States Senate,” November 15, 2006, http://www.hhs.gov/asl/testify/t061115.html (accessed September 26, 2007).

types of illnesses warrant upward reporting to the state or CDC (see Figure 10 and Figure 11). To respond to a national epidemic, there must be cooperation and communication between local, state, and national agencies. First, the illness must be

Epidemiologic Principles

- A rapidly increasing disease incidence (e.g., within hours or days) in a normally healthy population
- An epidemic curve that rises and falls during a short period of time
- An unusual increase in the number of people seeking care, especially with fever, respiratory, or gastrointestinal complaints
- An endemic disease rapidly emerging at an uncharacteristic time or in an unusual pattern (e.g., diseases usually spread by fleas in people who have no evidence of flea bites or no recent history of being near animals)
- Lower attack rates among people who have been indoors, especially in areas with filtered air or closed ventilation systems, compared with people who have been outdoors
- Clusters of patients arriving from a single locale
- Large numbers of rapidly fatal cases
- Any patient presenting with a disease that is relatively uncommon and has bioterroristic potential (e.g., pulmonary anthrax, plague, smallpox)
- Concurrent reports of increased animal deaths

Figure 10. Epidemiologic Principles.[110]

identified and victims treated, then the source must be found and isolated. Finally, any deficiencies in safeguards must be identified and corrected. An agroterror attack could differ from a natural incident only discretely, so it is crucial that health care professionals are able to recognize these crucial factors. Factors that would facilitate identification of an epidemic are called epidemiological principles (see Figure 10) and additional data that can help determine if the epidemic is the result of agroterrorism are called epidemiological clues (see Figure 11).

[110] From Peggy Lathrop and Linda Mann, "Preparing for Bioterrorism," *Baylor University Medical Proceedings*, 14:3 (2001), 222.

Epidemiologic Clues That May Signal a Covert Bioterrorism Attack

- Large number of ill persons with similar disease or syndrome.
- Large number of unexplained disease, syndrome or deaths.
- Unusual illness in a population.
- Higher morbidity and mortality than expected with a common disease or syndrome.
- Failure of a common disease to respond to usual therapy.
- Single case of disease caused by an uncommon agent.
- Multiple unusual or unexplained disease entities coexisting in the same patient without other explanation.
- Disease with an unusual geographic or seasonal distribution.
- Multiple atypical presentations of disease agents.
- Similar genetic type among agents isolated from temporally or spatially distinct sources.
- Unusual, atypical, genetically engineered, or antiquated strain of agent.
- Endemic disease with unexplained increase in incidence.
- Simultaneous clusters of similar illness in non-contiguous areas, domestic or foreign.
- Atypical aerosol, food, or water transmission.
- Ill people presenting near the same time.
- Deaths or illness among animals that precedes or accompanies illness or death in humans.
- No illness in people not exposed to common ventilation systems, but illness among those people in proximity to the systems.

Figure 11. Epidemiologic Clues That May Signal a Covert Bioterrorism Attack.[111]

2. Epidemiological Systems

Although epidemiology and disease reporting is a complex process, there are several systems that have been implemented to assure information flow and incident response capability. These systems facilitate communication between the primary care providers across the nation and the local, state, and federal agencies that have the resources and mandate to respond to a disease outbreak. While the primary care

[111] From Centers for Disease Control and Prevention (CDC), "The Public Health Response to Biological and Chemical Terrorism: Interim Planning Guidance for State Public Health Officials," http://www.bt.cdc.gov/Documents/Planning/PlanningGuidance.PDF (accessed October 15, 2007), 17.

providers continue to treat the patients already infected, this response is aimed at identifying the source of the outbreak to prevent further infections, investigation into the cause of the contamination, and measures to prevent further occurrences or an evaluation of current processes designed to mitigate disease.

The PulseNet system is “a national network of public health and food regulatory agency laboratories coordinated by the Centers for Disease Control and Prevention (CDC). The network consists of state health departments, local health departments, and federal agencies (CDC, USDA/FSIS, FDA).”[112] PulseNet not only consolidates reporting of epidemiologic indicators, but its members perform “standardized molecular subtyping (or fingerprinting) of foodborne disease-causing bacteria,” enabling the precise identification of strains of organisms at the genetic level.[113] Such a comparison enables the CDC and other agencies to identify potential nation-wide outbreaks precisely, and eliminate similar, but non-identical illnesses. “The strength of this system is its ability to identify patterns even if the affected persons are geographically far apart, which is important given the reality of U.S. food distribution systems.”[114] For example, based on a 1999 estimate, 73,000 infections and 61 deaths occur in the United States each year from *E. coli*.[115] However, because *E. coli* is a naturally occurring organism, there must be a method of discerning natural or isolated occurrences from deliberate or “common source” contaminations. Typing to the genetic level allows the CDC to identify specific strains of an organism such as *E. coli* to determine if the source of multiple illnesses can be isolated and attributed to intentional causes.

A related network called OutbreakNet allows the data collected by PulseNet to be shared and acted upon. OutbreakNet is a network of “public health epidemiologists at the local, state, and federal levels who investigate foodborne and diarrheal disease outbreaks.”[116] Member epidemiologists use the information obtained and maintained in

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[112] CDC, “PulseNet,” http://www.cdc.gov/PULSENET/ (accessed September 26, 2007).

[113] Ibid.

[114] King.

[115] CDC, “Escherichia coli O157:H7,” http://www.cdc.gov/ncidod/dbmd/diseaseinfo/escherichiacoli_g.htm (accessed October 9, 2007).

[116] CDC, “So What Exactly Are CDC´s PulseNet and OutbreakNet?” http://www.cdc.gov/about/stateofcdc/everyday/pulseNet.htm (accessed October 15, 2007).

PulseNet to identify and investigate suspected outbreaks of specific organisms. As a result of the information gathered through OutbreakNet, "tracing the implicated food back from consumption through preparation, to distributors, and sometimes back to a field or farm can help determine how the contamination occurred, stop distribution of the contaminated product, and prevent further outbreaks from occurring."[117]

The Foodborne Diseases Active Surveillance Network (FoodNet) is "the principal foodborne disease component of CDC's Emerging Infections Program (EIP). FoodNet is a collaborative project of the CDC, ten EIP sites, the U.S. Department of Agriculture (USDA), and the Food and Drug Administration (FDA)."[118] FoodNet enables active surveillance to identify occurrence of foodborne disease and identify specific sources of contamination. Although FoodNet offers robust capability, it is not active across the nation. In fact, as of 2004, only 10 states were participating in the program and the bacterial catchment area covered 44.5 million persons, only 15.1% of the United States population.[119]

There are two primary information systems that facilitate expedited reporting and information dissemination from the CDC to state health organizations. First, the Health Alert Network (HAN) is a "nationwide information and communication system that serves as a platform for the distribution of health alerts and prevention guidelines, distance learning, national disease surveillance and electronic laboratory reporting, and other initiatives to strengthen state and local preparedness."[120] Second, the Epidemic Information Exchange (EPI-X) is the CDC's "secure, web-based communications network that serves as a powerful communications exchange between CDC, state and local health departments, poison control centers, and other public health professionals. The system provides rapid reporting, immediate notification, editorial support, and

[117] King.

[118] CDC, "Foodborne Diseases Active Surveillance Network (FoodNet), http://www.cdc.gov/foodnet (accessed October 9, 2007).

[119] Ibid.

[120] CDC, "Fact Sheet; Public Health Infrastructure," http://www.cdc.gov/od/oc/media/pressrel/fs020514.htm (accessed October 15, 2007).

coordination of health investigations for public health professionals."[121] EPI-X allows the primary care providers and other reporting agencies the opportunity to consolidate reporting information to a centralized database that can be shared with other providers and response agencies.

3. Response and Investigation

"By the time people go to the hospital, an epidemic could have already broken out."[122]

Once an outbreak has been identified, the CDC and other government agencies activate incident response mechanisms. These measures can be as simple as a general health warning to the public, or can be as robust as a complete food type or specific product recall. In situations that lead to recalls of food, the CDC and the FDA coordinate actions to notify affected industries, as well as alert the public. These alerts are made through systems such as HAN and EPI-X, as well as through public access conduits such as the media.

Additionally, as part of the response, these agencies work to determine the cause of the outbreak, and whether the contamination was natural or intentional. This portion of the investigation is called attribution, and can be the most difficult stage of any investigation, because of the nature of illness caused by agricultural contamination.[123] "Common and naturally occurring pathogens and the infections they create raise little medical suspicion and are not assumed to be the weapon of choice for terrorists."[124] Only when large numbers of the same type of illness are reported and the same strain of bacteria is identified can a determination be made that there is probably an outbreak. Immediate investigation into the source of the contamination is vital. A law enforcement response to a suspected deliberate contamination requires careful consideration of

[121] CDC, "EPI-X, the Epidemic Information Exchange," http://www.cdc.gov/mmwr/epix/epix.html#1, (accessed October 9, 2007).

[122] Scott Gottleib, "The United States is Not Prepared for a Bioterror Attack," in Lisa Yount, ed., *Fighting Bioterrorism* (San Diego: Greenhaven Press, 2004), 21.

[123] Brian Bernett does an excellent job of examining the attribution process for which an outbreak requiring the coordination between public health and law enforcement officials. For a detailed examination of attribution, see Bernett, especially Chapt IV.

[124] Bernett, 66.

evidence collection, such as compliance with rules of evidence to include chain of custody concerns for later prosecution. However, since deliberate contaminations would likely mimic a natural outbreak initially, the law enforcement response might not occur immediately. This leads to additional challenges related to evidence contamination and loss, and increases the difficulty of identifying the contaminator(s) when the initial response is a purely medical one.

C. CASE STUDY

1. Reporting

The 2006 Spinach *E. coli* outbreak is a useful case study in evaluating the strengths and weaknesses of U.S. systems used to identify, respond and manage outbreaks of food borne illnesses. This outbreak demonstrated that a food-source contamination can be identified, that local, state and federal agencies can respond in a coordinated fashion, and the public can be quickly notified, the product isolated, and overall casualties minimized. However, this case also shows the greatest weakness in the system: the identification of contamination after the first people become ill, but before it becomes an epidemic.

The PulseNet system was instrumental in the identification of the 2006 *E. coli* outbreak. On September 8, 2006, it facilitated identification of the first cluster of illnesses attributable to *E. coli* in Wisconsin. On September 13, a second cluster was identified in Oregon, along with additional potential cases in several other states. By September 14, fresh spinach had been implicated as the source of illness, and 50 cases were reported. On September 14, the public health community was notified of the outbreak via HAN and EPI-X, and by September 15, the U.S. media began relaying the warning to the public not to eat fresh spinach.[125] Contaminated spinach later determined to have been processed on August 14 caused illnesses that would spread across the nation. By September 16, 2006, 102 persons were identified as infected with the

[125] CDC, "What CDC and Other Agencies Did in Response to the Outbreak of *E. coli* O157:H7 Infections from Spinach," http://www.cdc.gov/ecoli/2006/september/response (accessed October 3, 2007).

outbreak strain of *E. coli* O157:H7. Of these, 52 were hospitalized, 16 developed kidney failure called hemolytic-uremic syndrome (HUS), and 1 person died. Illnesses were reported from 19 states.[126]

One of the greatest challenges with identifying food borne illness is the victim's reporting time from ingestion of the contaminant to onset of symptoms and seeking medical attention (see Figure 12). If numerous people are exposed to a bacterium such as *E. coli* at the same time (as in this example, consuming spinach from the same batch harvested, bagged and sold around the same time), by the time they all seek medical attention and samples are submitted for analysis, large numbers of people could have already been sickened.

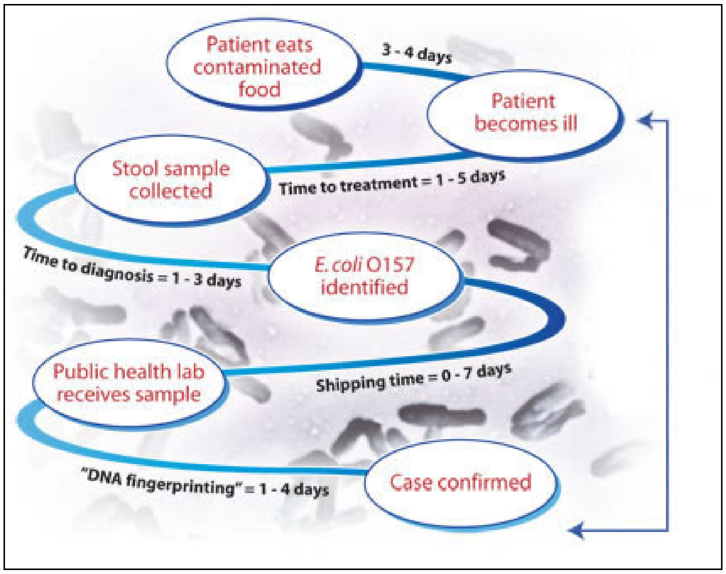

Figure 12. CDC's Estimated Timeline for Reporting of Cases[127]

It is important to note that the first infection was determined to have occurred on August 19; however, the first determination that there was an outbreak was not made

[126] California (1 case), Connecticut (2), Idaho (4), Indiana (4), Kentucky (4), Maine (2), Michigan (6), Minnesota (1), New Mexico (5), Nevada (1), New York (7), Ohio (10), Oregon (5), Pennsylvania (3), Utah (14), Virginia (1), Washington (2), Wisconsin (29), and Wyoming (1); (CDC, "Update on Multi-State Outbreak of *E. coli* O157-H7 Infections From Fresh Spinach; September 16, 2006," http://www.cdc.gov/ecoli/2006/september/updates/091606.htm (accessed October 3, 2007)).

[127] From CDC, "Timeline for Reporting of *E. coli* Cases," http://www.cdc.gov/ecoli/reportingtimeline.htm (accessed November 26, 2007).

until September 8.[128] While Figure 13 shows a dramatic cluster of illnesses centered on August 31, *E. coli* sicknesses caused by Salinas contaminated spinach actually covered a much greater period. By the end of the outbreak in early October, 199 persons had been reported infected by *E. coli* O157:H7, of which 102 had been hospitalized, 31 developed HUS, and 3 died.[129]

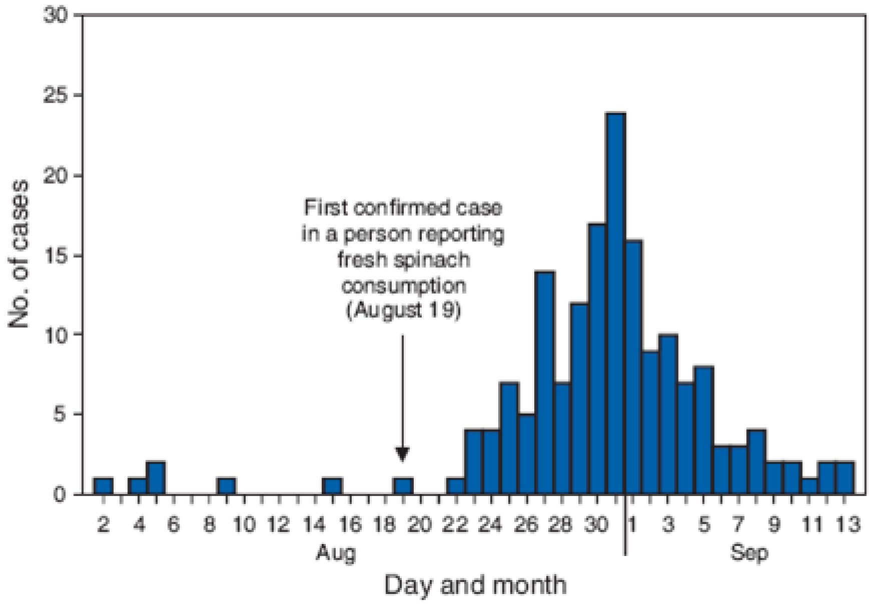

Figure 13. Number of confirmed cases (N = 171) of *E. coli* serotype O157:H7 infection, by date of illness onset, reported as of September 26, 2006.[130]

2. Response

As soon as the initial outbreak was identified, the CDC and FDA issued a blanket health warning against consumption of fresh spinach. Initial information was insufficient to allow more specific warnings, so the federal agencies opted for the most conservative approach: a comprehensive warning. On September 14, the FDA advised the public not

[128] CDC, "Multiple States Investigating a Large Outbreak of *E. coli* O157:H7 Infections, September 14, 2006," http://www2a.cdc.gov/HAN/ArchiveSys/ViewMsgV.asp?AlertNum=00249 (accessed October 3, 2007).

[129] CDC, "Update on Multi-State Outbreak of *E. coli*."

[130] From CDC, "Ongoing Multistate Outbreak Of Escherichia Coli Serotype O157:H7 Infections Associated With Consumption Of Fresh Spinach --- United States, September 26, 2006," http://www.cdc.gov/mmwr/preview/mmwrhtml/mm55d926a1.htm (accessed October 17, 2007).

to eat bagged fresh spinach, but then revised the warning on September 15 to cover all fresh spinach or salad blends containing spinach.[131] Within days, supermarkets across the nation pulled spinach from their shelves. Additionally, by September 21, 2006, three companies initiated voluntary recalls of their spinach products: Natural Selection Foods of Salinas (September 15), River Ranch of Salinas (September 17), and RLB Food Distributors of West Caldwell, New Jersey (September 19).[132] This response by the CDC and FDA was nearly immediate, and showed the successful interagency coordination and response. However, as Figure 13. shows, the number of illnesses being reported had dropped significantly by the time these agencies began their response. Although the data in Figure 13 ends the day the recall begins, the trend of infections was clearly decreasing by the time the CDC and FDA responded. In fact, over the next three weeks, only 18 more people became ill from spinach, an average of less than one per day.

3. Investigation

In the case of the Salinas spinach contamination, the process of tracing the contamination back to its source was accomplished quickly. Almost immediately after identification of the second outbreak (in Oregon), investigators were able to determine the source of the contamination: bagged spinach from the Salinas Valley, California. "A contaminated bag of Dole baby spinach found Wednesday [September 13, 2006] at the New Mexico home of a person who fell ill helped investigators focus in on the source of the current *E. coli* scare."[133] Investigators were able to use this specific bag to trace the product back to its source. Once California produce was identified, the California Food Emergency Response Team (CalFERT) was notified and on September 14 an investigative team arrived in Salinas.[134]

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[131] Ibid.

[132] Patricia Griffin, Karl Klontz, Phillip Tarr, "COCA Conference Call—*E. coli* O157:H7 Outbreak (September 21, 2006)," http://www.bt.cdc.gov/coca/summaries/pdf/E_coli_Sept_21_2006final.pdf (accessed September 28, 2007).

[133] "Feds: New Safety Plan Required Before Spinach Is Sold," NBC, September 11, 2006, http://www.nbc11.com/news/9903292/detail.html (accessed October 16, 2007).

[134] For a detailed analysis of the investigation, refer to CA Department of Health Services and U.S. FDA , "Investigation of an Escherichia coli O157:H7 Outbreak."

While the initial best information was generic with respect to the source of contamination (fresh spinach), as the investigation progressed authorities were able to narrow the source after a process of 'tracebacks,' in which "records are collected sequentially to elucidate the path of product associated with illness to travel from the point of consumer purchase all the way back, ideally, to the production side."[135] As a result of this vigorous process, by September 18, 2006, it was determined that all brands of spinach linked to the outbreak were grown in Salinas, California. As a result of this information, the FDA revised its health warning and advised against eating spinach from three specific counties in California.[136]

4. Attribution

The cause of the 2006 *E. coli* outbreak in spinach remains unknown. Investigators concluded: "No definitive determination could be made regarding how *E. coli* O157:H7 pathogens contaminated spinach in this outbreak."[137] California authorities believe it was a natural occurrence, most probably caused by contamination of the spinach in the fields. "Potential environmental risk factors for *E. coli* O157:H7 contamination identified during this investigation included the presence of wild pigs in and around spinach fields and the proximity of irrigation wells used for ready-to-eat produce to surface waterways exposed to feces from cattle and wildlife."[138]

5. Financial Impact

The Salinas Valley region of California is commonly called "America's Salad Bowl." According to the California Farm Bureau Federation approximately 74 percent of the fresh-market spinach grown in the U.S. comes from California.[139] As will be discussed below, regional concentration of a specific crop has both positive and negative effects. Positively, this concentration enables authorities to quickly identify the source of

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[135] Griffin et al.

[136] CDC, "What CDC and Other Agencies Did."

[137] CA Department of Health Services and U.S. FDA , "Investigation of an Escherichia coli O157:H7 Outbreak."

[138] Ibid.

[139] "Markets, Restaurants Pull Popular Spinach Greens from Shelves, Menus," *Knight-Ridder Tribune Business News*, September 19, 2006.

any contamination, respond, and isolate the crop. However, regional concentration can exacerbate the resulting economic hardship. In the Salinas *E. coli* case, even though the spinach contamination was eventually isolated, the entire Salinas Valley spinach industry was initially implicated and bore the brunt of the immediate economic costs as the contaminated crops were pulled from the shelves, and the linger costs of consumer backlash.

Within Monterey County spinach is an important crop, sold both by itself and as an additive to bagged salads. With 2005 sales exceeding $188 million, spinach accounts for approximately 5% of the region's $3.4 billion agricultural output.[140] Additionally, as a result of spinach becoming an integral part of packaged salads, spinach sales increased nearly 36 percent from 2002 to 2005.[141] Total 2005 bagged salad sales from Monterey County topped $132 million.[142]

The August 2006 *E. coli* contamination had significant impact on the economy of the region. According to figures released by the Perishables Group, "sales figures through Dec. 23 from 16,000 conventional supermarkets, not including big-box stores such as Wal-Mart or Costco, showed an overall 14 percent drop in spinach sales [from the previous year]…bulk spinach dropped by nearly half and even packaged salad without spinach dropped about 10 percent.[143] Only once the contamination was contained and spinach returned to the shelves was the economic impact of the incident able to be assessed. According to the 2006 Monterey County Crop Report, 2006 sales of spinach were down $77 million compared to 2005 and bagged salad sales fell by $10.5

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140 California Department of Food and Agriculture, "Monterey County Crop Report 2006," http://www.co.monterey.ca.us/ag/pdfs/cropreport2006.pdf (accessed October 18, 2007).

141 Kate Forgach, "Latest Food-Safety Scare Hits Local Growers Hard," *Northern Colorado Business Report*, September 29, 2006.

142 California Department of Food and Agriculture, "Monterey County Crop Report 2006."

143 Janet Frankston Lorin, "Consumers Still Worried About Spinach after *E. coli* Contamination," *The Associated Press State & Local Wire*, February 4, 2007.

million from the previous year.[144] Jim Bogart, president of the Grower-Shipper Association believes the full economic impact on local agriculture likely won't be known until 2008.[145]

The direct short term impact can and has been measured, but the loss in consumer confidence and long term impact has yet to be realized. In fact, some analysts believe it may take a full five years for the spinach market to recover from the damage it suffered from the *E. coli* scare.[146] Sales of salad mix dropped by approximately 50 percent after the September *E. coli* outbreak, and took months to recover. In February 2007, the sales for mixed salads rose to only about 75 percent of its previous levels, and conventionally grown bunched spinach were about 80 percent of previous sales.[147] Unless and until consumer confidence is restored, the region will continue to be adversely affected by the ripples of the September 2006 outbreak. However, while regionally this loss remains significant, it represents only a fraction of the $10.2 billion generated annually from the vegetable sector (top 35 vegetables).[148]

6. Analysis

While this case shows that systems in place within the U.S. are effective in collecting and conveying trend information to national agencies such as the CDC and FDA, it also highlights the greatest system vulnerability; identifying illnesses before they become an epidemic. This case shows that while the national systems may adequately report the illnesses, they are only activated after people begin to report their illnesses, and the mechanisms only begin to respond when clusters of illnesses appear. In fact, in this case, the majority of the people who got sick as a result of eating contaminated spinach did so before the nation was able to identify that there was even a problem and before the national response system was initiated. Although one might think this it is good that the

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[144] California Department of Food and Agriculture, “Monterey County Crop Report 2006.”

[145] “What Will '07 Bring?” *The Californian*, January 1, 2007.

[146] Greg Edwards, “Virginia Spinach Growers Hopeful Their Harvest Finds A Market,” *Richmond Times-Dispatch,* September 27, 2006.

[147] Lorin.

[148] USDA, “USDA National Agricultural Statistics Service - Quick Stats, U.S. & All States Data – Vegetables,” http://www.nass.usda.gov/QuickStats/Create_Federal_All.jsp (accessed October 19, 2007).

number of people who got sick during the response phase is low, the reduction in illness was *not* due to any concerted effort, but rather to the fact that the contaminated bagged spinach reached its best-by date and became largely unavailable for consumption. The first cluster of illnesses was identified on September 8, 2006, by which time the majority of people who would be sickened in the outbreak had already consumed contaminated spinach and become symptomatic. By the time the nation-wide alert and recall were initiated (September 14), 171 of the 199 infections had already occurred. Thus, while it is possible that the recall prevented further infections, the distribution of illnesses shows that the number of prevented infections was at best very small. Figure 13. shows that the number of illnesses was decreasing by the time the first and second clusters were identified, and as the trend continued, dropped to an average of less than one per day until the contaminated spinach was no longer in supply channels and the last case was reported. Effectively, the data indicates even without a concerted response by health agencies to warn consumers of the contamination, the illnesses would likely have continued to decrease until they reached zero as the contaminated spinach naturally disappeared from the market. What epidemiology accomplished in this case was to facilitate the response, investigative, and attribution phases, enabling the FDA to initiate food warnings, and working toward helping the public regain confidence in the food supply. Even though the warnings were realistically superficial, they led the nation to believe the FDA was doing something about a national health problem.

Although the epidemiologic investigation can be laborious, the response phase to widespread food contamination can be initiated very quickly. In the Salinas spinach case the response was immediate and effective. Within one day of the identification of the second cluster of illnesses, a nation-wide health warning was published, supermarkets were pulling spinach from their shelves, and three large spinach companies had initiated voluntary recalls. Investigators worked with the victims to identify common consumption items and had narrowed the production are to a relatively small region in California. An investigative team was dispatched to the suspect area and the investigation phase began.

The investigation into the source of the *E. coli* in this case, while thorough, was ultimately inconclusive. Careful examination of harvesting methods as well as the

processing and packaging procedures seemed to eliminate the likelihood of post-harvesting contamination. Investigators concluded that environmental factors led to the contamination, most likely wild animals in the area, nearby cattle, or contaminated groundwater, and that there was no wrong-doing or lapse in protocols by any of the companies involved. However, no definitive source could be identified. This suggests that in isolated cases of contamination attribution is difficult. While the investigative agencies' conclusion that the Salinas contamination occurred naturally seems reasonable, it could be that this incident was in fact intentional, perhaps even a terrorist group's test of the national response and/or an effort to gauge the effectiveness of a more significant attack such as the one modeled in the counterfactual case below.

D. COUNTERFACTUAL U.S. CASE

1. The U.S. at Risk

The Salinas *E. coli* case is an example of a single-crop contamination that had significant financial repercussions regionally. In the context of the overall U.S. GDP, the impact was negligible. However, based on this actual case it is possible to model a multi-crop counterfactual case and then to evaluate the likely financial impact of an intentional multi-crop contamination. Spinach is only one of many crops that are geographically concentrated in specific regions of the U.S. (see Figure 14). California alone produces the majority of the nation's vegetable production. According to the USDA, in 2006 California produced over 52 percent of the nation's top ten vegetables (see Figure 15) and 51.3 percent of the top 34 vegetables produced in the U.S. (see Figure 16).[149]

[149] USDA, "Quick Stats, U.S. & All States Data – Vegetables."

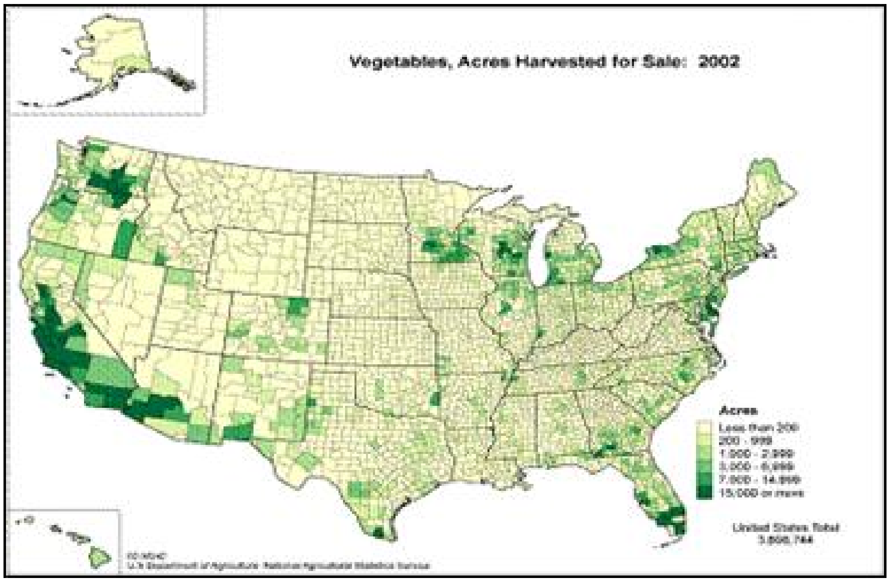

Figure 14. Vegetables, Acres Harvested for Sale, 2002.[150]

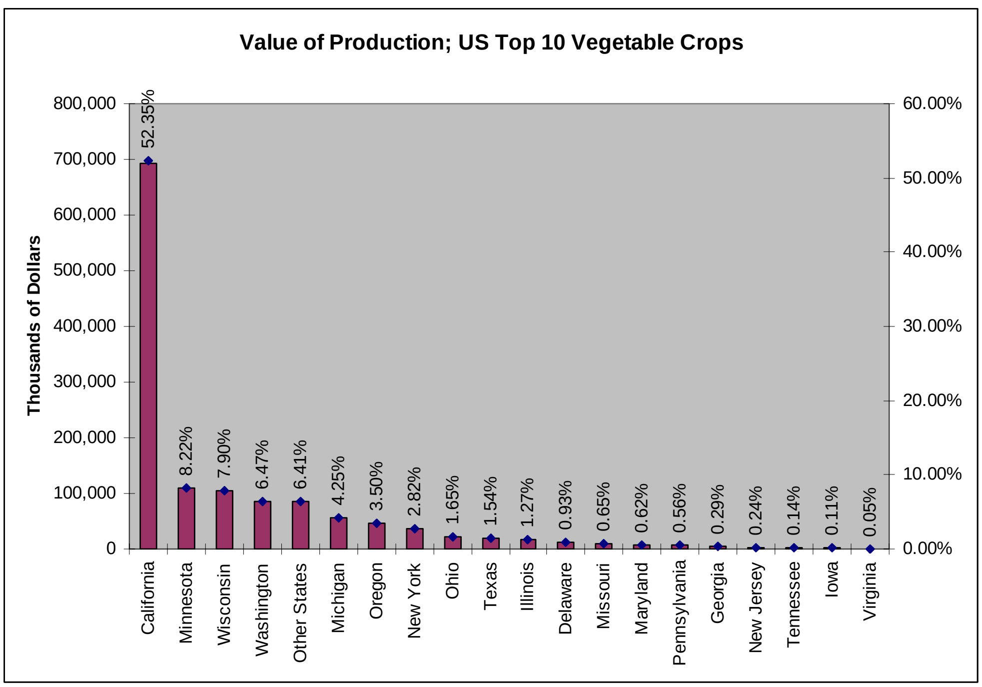

Figure 15. Value of Production; US Top 10 Vegetable Crops[151]

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150 From USDA, "Vegetables," http://www.nass.usda.gov/research/atlas02/pdf/02-M241-RGBDot1-largetext.pdf, (accessed November 14, 2007).

151 After Ibid.

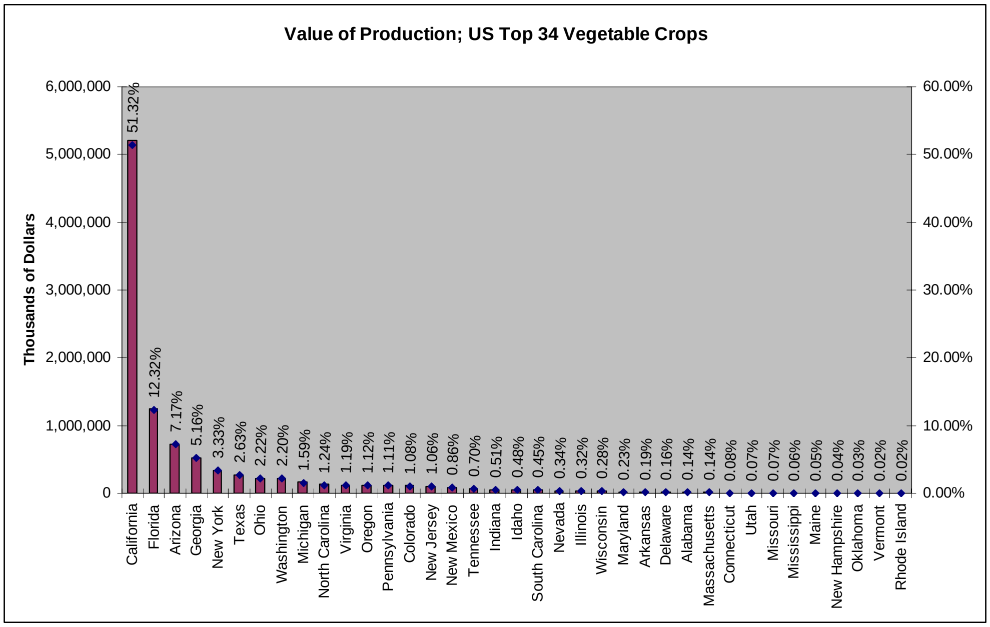

Figure 16. Value of Production; US Top 34 Vegetable Crops[152]

Along with spinach, California also leads the nation in the production of lettuce, producing between 77 and 89 of combined lettuce and spinach earnings in 2006 (see Figure 17). Total U.S. lettuce and spinach crops were valued at over $2 billion in 2006 (see Figure 18), which makes them collectively a potentially lucrative target for a terrorist organization wishing to inflict significant economic and psychological damage upon the U.S. This counter-factual case will consider the likely effects of a simultaneous attack on the main three types of lettuce (leaf, romaine, and head) long with spinach.

[152] After USDA, "Quick Stats, U.S. & All States Data – Vegetables."

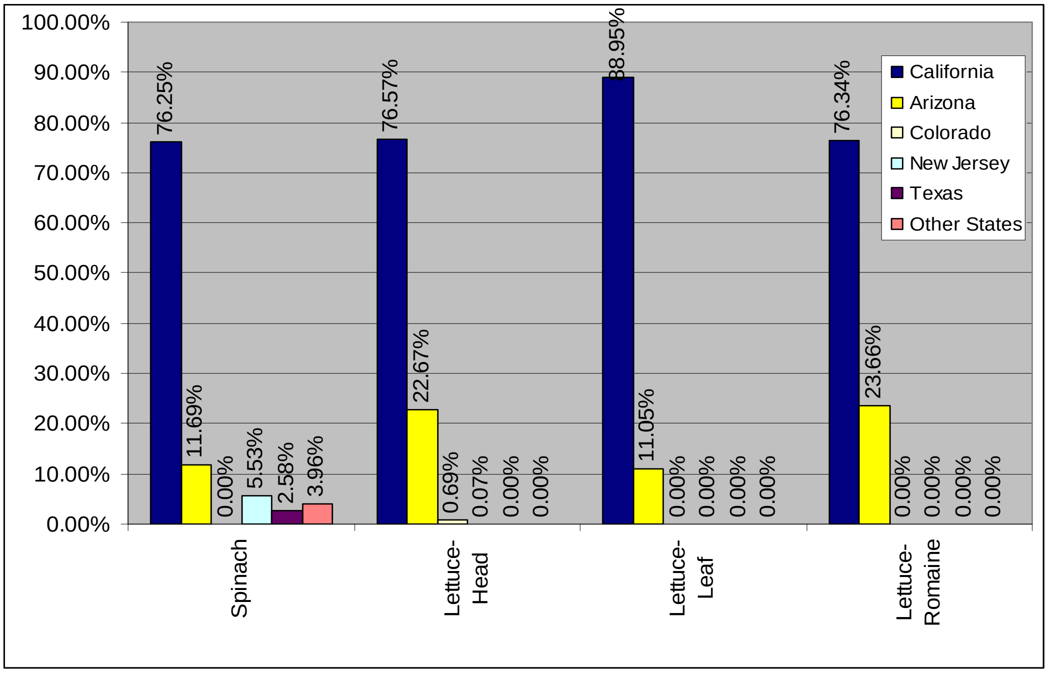

Figure 17. Spinach and Lettuce Percentage of Production[153]

	Harvested area--1,000 acres		Production--Million cwt		Crop value--$1,000 1/	
Commodity	2005	2006	2005	2006	2005	2006
Lettuce						
Head	177.40	174.60	65.75	58.69	1,019,218	976,923
Leaf	64.60	71.10	15.89	17.15	530,708	599,222
Romaine	60.40	61.00	19.93	19.81	386,291	427,796
Spinach	45.70	45.60	7.58	6.21	172,114	181,765
Total	348.10	352.30	109.15	101.86	2,108,331	2,185,706

1/ Crop value from 2004 forward is based on grower prices

Figure 18. Fresh vegetables: U.S. area, production, and crop value, 2005-2006[154]

Because the three lettuce crops and spinach are all highly concentrated in California, they also pose attractive targets in terms of ease of access. Contaminants could easily be introduced by either a lone individual, or more likely several members of an organization acting in concert. The contaminants could be introduced simultaneously or within days of each other. In either case, the crop contamination would likely follow

[153] After USDA, "USDA National Agricultural Statistics Service - Quick Stats, U.S. & All States Data – Vegetables."

[154] After Ibid.

the course of the Salinas outbreak. In an alternate scenario, contamination could be introduced in recurring intervals, varying either types of crops or originating locations. Each of these recurring contaminations would follow the same pattern, but the overall impact would be more significant than a single outbreak.

2. Outbreak

As in the Salinas spinach contamination, a combined spinach and lettuce contamination would likely be characterized by clusters of illnesses throughout the U.S. Since California produce represents the lion's share of both spinach and lettuce, it is shipped and consumed throughout the nation. Produce contaminated even at only a few originating sites would likely be transported to different states, and sicken those eating it.

Spinach production in 2006 yielded 6.21 million cwt (cwt = hundred weight = one hundred pounds). This represents 6.10 percent of the total spinach and lettuce crop for 2006. If lettuce and spinach were contaminated at the same percentage and distributed throughout the country, worst case contamination would follow the same percentages. If the number of casualties in the Salinas *E. coli* case is estimated to be 6.10 percent of the casualties for a multi-crop contamination, an estimated 3264 people could fall ill and 49 people die from *E. coli* in spinach and lettuce.[155] Because fresh lettuce and spinach are shipped quickly throughout the nation and consumed while fresh, these illnesses would likely occur in many different areas; however, the rate of illnesses would likely follow the same pattern as the Salinas *E. coli* case. The first cases of illness would appear nearly immediately, with the peak reaching over 400 people ill approximately two weeks later.[156] Although these illnesses would appear throughout the nation, they would likely be reported in clusters, and enter the nation's epidemiological systems in similar fashion to the Salinas case.

Because the first line of detection is at the local level, namely primary physicians, emergency rooms, and the like, the increased reporting burden would be dispersed

[155] If spinach at 6.21 million cwt is 6.10% of the total spinach and lettuce production, then assuming 199 ill and 3 dead are 6.10% of the total casualties for a multi-crop outbreak, one can estimate 3264 people ill and 49 dead.

[156] In the Salinas case, 25 people were reported ill at the peak of the illnesses, 13 days after the first case (see Figure 13.). This represents 12.5% of the total ill during the outbreak.

through the different locations, and would most likely be manageable. As highlighted in the CDC "Epidemiologic Clues That May Signal a Covert Bioterrorism Attack" chart (Figure 11) an increase in case reporting would likely lead to an early identification of the intentional nature of the contamination, initiating an early law enforcement response. However, with a multi-crop contamination, there would likely be confusion in the investigation phase of the response. In the Salinas case, it was a relatively quick process of identifying the source, as all the victims were determined to have eaten bagged spinach or salad containing spinach. In this counter-factual case, the victims would all report eating lettuce or spinach, but also a host of other foods. In fact, the investigators might initially discount spinach and lettuce as the cause of illness as not all those sickened would report eating either.

If the contamination were repeated in intervals, additional casualties could be expected. However, each subsequent contamination would likely be less significant, for two reasons. First, as shown in the Salinas case, consumption of the affected food would already have decreased, and thus fewer people would be exposed. Second, people dying as a result of contaminated food would likely decrease dramatically as the public would be more prone to seek medical treatment at the first sign of symptoms as general awareness of food-borne illnesses would be heightened. While the first outbreak would follow the pattern outlined above, subsequent cases would have a steeply decreasing curve for both people sickened and killed by the contamination.

In the Salinas case, once the illnesses were linked to food products, identification of not only the specific food but also the originating location was nearly immediate. This allowed the response team to begin the investigation into the suspected farms. In the multi-crop outbreak hypothesized here, the identification of the source of contamination would likely not be as quick. The increase in illnesses and diversity of food consumed would increase the effort required to identify the source. However, once *E. coli* was identified as the cause, the resulting response would more likely include a law enforcement contingent, something lacking in the Salinas case. This additional piece of the response would facilitate evidence collection and incident attribution.

Although there might be initial challenges in identifying the sources of contamination, the Salinas *E. coli* case shows an outbreak of this type will largely run its course with or without government response. This observation holds true for both the one time multi-crop scenario and serial contaminations over time.

3. Financial Impact

For the purpose of this estimate, simple extrapolation will be used based upon the Salinas case to estimate the overall impact of an intentional, multi-crop contamination of spinach and the three types of lettuce examined above.

In 2006 the U.S. spinach crop had a value of nearly $182 million, and suffered a $77 million loss as a result of the Salinas contamination. This represents a 42.3 percent loss in revenue. For this same period leaf, romaine, and head lettuce crops had a value of over $2 billion, with the majority of the market coming from head lettuce. Combined with spinach, these leafy vegetables had a combined value of $2,185,706,000. Applying a 42.3 percent loss to the 2006 crop values of leaf, romaine, and head lettuce and spinach leads to an estimated total loss of at least $924.56 million. Additionally, because of the probable delays in identifying the sources of contamination, initial releases from the FDA might warn against fresh produce consumption until the definitive sources were identified. The resulting consumer backlash would likely impact other sectors of the economy as well. While this secondary economic impact is harder to estimate, these additional affects cannot be discounted.

If the market share in California is applied to determine a correlating loss based on a decrease in California revenues, the percentages of lettuce and spinach produced in California need to be compared with the crop values. In 2006 California spinach represented 76.25 percent of the spinach produced in the U.S, and was valued at $138.6 million (see Figure 17). Although all spinach manufacturers were initially impacted by the spinach recall in the days after the announcement of the contamination in Salinas, the overall impact to spinach growers outside the California area was less significant than the impact to California growers. If one applies the percentage of spinach grown in California and applies the market loss to that market share ($77 million out of $138.6 million), a 55.56 percent loss is determined. Applying this percentage to the lettuce

values produces a different, but similar, estimate in loss. A 55.56 percent loss to the California share of the market leads to a total estimated loss in excess of $970 million (see Figure 19). With the caveat that the margin of error in these calculations could be

Commodity	Value of production ($K)	Estimated Loss Percentage	Expected Loss per Crop ($K)
Spinach	138,600	55.56%	$ 77,000.00
Head	748,000	55.56%	$ 415,555.56
Leaf	532,980	55.56%	$ 296,100.00
Romaine	326,592	55.56%	$ 181,440.00
Total Value	1,746,172	55.56%	$ 970,095.56

Figure 19. Estimation of California Crop Value and Estimated Loss

significant, this counter-factual multi-crop intentional contamination would lead to a $925 to $970 million loss in agricultural revenues within the U.S. If the contamination was recurring, the loss would clearly increase. Although the effects of each repetition of the contamination would be significantly lower than the one before it, repeated outbreaks of *E. coli* would lead to long term consumer distrust in the safety of produce (especially spinach and lettuce), and would likely decimate its sale. One could expect revenue from spinach and lettuce to be nearly non-existent until the government and industry took steps and implemented programs to monitor the safety of the crop.[157] One could expect a total loss of fresh spinach and lettuce revenues as long as the attacks continued, which would mean a loss of approximately $1.7 billion annually.

4. Psychological Impact

As with the previous case study, even more important that the direct financial impact of this contamination is the public's reaction and resulting loss in confidence in the safety of the food supply. While this latter impact is harder to measure than direct dollar costs, it is likely a key factor in the outcome of this counter-factual case.

[157] For discussion of government and industry partnership in regulating agricultural safety, refer to C. Paul Young's unpublished Master's Thesis, "Method Or Madness: Federal Oversight Structures for Critical Infrastructure Protection," Naval Postgraduate School, December 2007.

There has been much written on public reaction to unconventional attacks, and the Anthrax attacks of 2001 serve as an example of public reaction to such an event. According to Dr. Shulamith Kreitler, the public can be expected to respond to an incident of an unconventional (biological or chemical) attack with fear, helplessness, vulnerability, and grief or sadness.[158] This is manifested in various ways, and after the anthrax letters, the public responded dramatically. "The nation was thrown into an unwarranted frenzy of fear, and huge quantities of antibiotics were swallowed unnecessarily. Government and private buildings were closed for weeks, and one large post office in Washington didn't reopen for almost a year and a half, and some employees refuse to work there even now."[159] People across the country rushed out to buy duct tape and sheets of plastic to seal their homes in case of a dramatic airborne anthrax attack. In fact, some believe the public's over-reaction is more dangerous than the attack itself. "[J]udging from the reaction to the anthrax situation, they [the public] are more in danger of scaring themselves into immobility than dying from an attack that will probably never come…"[160]

This reaction was not only seen in response to the Anthrax attacks, but also after the Salinas *E. coli* outbreak. After the period of contamination, the public showed some reluctance to immediately resume their previous spending patterns. The reduced sales trends in spinach indicate the American public has not fully regained their trust in the safety of spinach. One can expect an even more significant backlash to this multi-crop counterfactual case. Further, if the contamination were attributed to intentional contamination, this reaction would be heightened even further. Additionally, the more time between the initial outbreaks and identification of the contamination source, the greater the level of fear and panic rising in the public. Finally, if the attacks were recurring, this increasing level of fear and panic would be greater still. Even during the periods between attacks would be times of uncertainty and distrust, as the public anticipated subsequent attacks. As illnesses continued to be reported across the nation,

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[158] Shulamith Kreitler, PhD, "Coping With Panic and Fear of a Nonconventional Threat," *Clinics in Dermatology* 2 (2002): 413–419.

[159] Margot J. Fromer, "Dr. Fauci on Bioterrorism: Threat But Not Cause for Panic," *Oncology Times* 25:10 (2003): 45.

[160] Ibid.

state and federal agencies would likely be seen as ineffective and powerless to assure the safety of the nation's food. Not only would this fear manifest in consumer backlash as discussed above, but also in over-prophylaxis as seen in the Anthrax case and panic stockpiling of canned and other processed foods.

E. CONCLUSION

The 2006 national outbreak of *E. coli* contamination in spinach was an incident of national significance. Although only three people died and 200 were sickened (a small number compared to the average number of food-borne illness reported every year), it was significant because it was concentrated, both in time and source. The national spinach market ground to a halt, and long term affects are still being felt by spinach growers in California. However, on a national level, this case is less significant. Because spinach was identified as the source of contamination, other products (with the exception of bagged salads that include spinach) were largely not affected. The $77 million loss in spinach sales is significant to the Salinas Valley region, but pales when compared to the $1 trillion role agriculture plays in the U.S. economy.

In the 2006 *E. coli* outbreak, the national health and epidemiology systems were effective in identifying clusters of ill people and tracing the source of the contamination to the spinach fields in Salinas and dispatch response and investigative teams. While source identification enabled government and industry to work together to remove potentially contaminated products from the stores, it is was likely there was already reduced amounts of contaminated products available due to expiration and "best if used by" dates that were expiring. Overall, the system worked as it was designed; however, it did not significantly impact the number of people who contaminated food. By the time the cause was identified and response mechanisms in place, the outbreak was largely over. Therefore, while the system appears to be largely ineffective in preventing or significantly reducing a nation-wide *E. coli* outbreak, the very nature of a bacterial outbreak such as *E. coli* renders this largely unimportant, because by the time people start getting sick and seeking medical care, the outbreak is likely to have already peaked, as in this case.

IV. CONCLUSION

The counterfactual cases presented in the previous chapters allow for a tentative evaluation of the debate within escalation theory presented in Chapter 1. Given escalation theories assumption that globally established terrorist groups must maintain or increase their level of violence or impact with each subsequent attack, what do these case studies tell us about the probability of terrorist organizations turning to agroterror as their next course of action? This thesis asks a series of questions: Would an attack against the nation's agriculture base be likely to create enough casualties, economic disruption, and/or fear and uncertainty to be attractive to terrorists? Is it likely that the impact of an attack would be largely contained by the systems in place, or do the vulnerabilities created by centralized distribution and limited response create an attractive target for the terrorists? Additionally, while these response measures have been effective in recent and admittedly limited natural outbreaks, would multiple attacks overwhelm the system?

A. MAJOR QUESTIONS

1. Would an attack against the nation's agriculture base be likely to create enough casualties to meet the threshold of escalation?

In both the FMD and *E. coli* case studies and associated counterfactual cases, the number of human casualties is relatively minimal. In the FMD case, one can expect no deaths attributable to FMD, as the disease targets livestock and is readily detected before contaminating the food supply. The same holds true with illness; one can expect detection of infected cows prior to their introduction into the food chain, and even if detection failed, infected meat will not make people ill. In the counterfactual multi-crop *E. coli* attack proposed in Chapter 3, total casualties are estimated to be approximately 50 dead. Although repeated attacks might lead to slightly higher numbers, total deaths would still be expected to be insignificant in comparison to other global terrorist attacks. Therefore, agroterror attacks against the U.S. are not likely to produce casualties in sufficient numbers to constitute escalation.

2. Would an attack against the nation's agriculture base be likely to create enough economic disruption to meet the threshold of escalation?

Of the two counterfactual scenarios, a FMD attack would clearly have more significant financial impact on the nation. While an *E. coli* attack would have regional impact, the potential $1 billion economic loss represents a negligible percentage of U.S. GDP -- less than 0.01%. Certainly, those directly reliant upon the vegetable sector for their livelihood could face significant economic hardship; however, in the larger perspective, such an attack would be an isolated blip in the U.S. economy as a whole. FMD, the other hand, would have a much larger national impact. Direct costs of a national FMD outbreak are estimated at between $50 and $100 billion, or close to 1% of annual GDP, with indirect costs likely even higher over the course of the epidemic and recovery phases. While FMD outbreaks pose a significantly greater economic challenge than an *E. coli* attack, livestock still represents only a small sector impact on the U.S. economy. To compare, in a summary of eight separate analyses, the GAO estimated the economic impact of the September 11th attacks at between $83 and $191 billion, in both direct and indirect costs.[161] While the total economic damage inflicted by a major FMD attack could be just as costly, it important to note that the estimated economic impact of such an attack would be spread out over a 5 to 10 year period. The fact that the economic impact of a FMD outbreak would be spread out over such a long period reduces the impact of the overall cost. Thus, although the total monetary impact of an FMD attack might match the economic impact of the September 11th attacks, such an attack still would not meet the threshold of escalation because of the dissipated impact over time.

3. Would an attack against the nation's agriculture base be likely to create enough fear and uncertainty to meet the threshold of escalation?

Attacking a nation's food source has the potential to create panic in its public. While a nation can survive by altering flying patterns or accepting other inconveniences in travel security, people cannot survive without a safe food supply. However, neither of

[161] GAO, "GAO-02-700R; Review of Studies of the Economic Impact of the September 11, 2001, Terrorist Attacks on the World Trade Center, (Washington D.C.: GAO, May 2002), 2-3.

these counterfactual cases shows the potential to impact Americans' way of life for any significant period of time.

A FMD attack would initially create significant fear and uncertainty as a deliberate attack would likely lead to a nation-wide epidemic, affecting large portions of the cattle, sheep, and swine sectors. However, because FMD infections would not spread to humans, the uncertainty would center on specific sectors of the food supply. There would be significant reductions in availability of meat from the affected sectors, but that only means people would have to adjust their consumption habits. Psychological impacts of the recovery efforts (funeral pyres, piles of carcasses, etc), could be more significant, but even those affects would be relatively short-lived and supportable by crisis response capabilities, and have little residual impact after the recovery phase.

As the Salinas case study showed, an *E. coli* outbreak is largely self-limiting, and would run its course over time. Even though repeated attacks on the produce sector would have a more discernable impact, consumers would likely adjust their buying habits to avoid the at-risk product until assured of their safety. Americans could rely upon cooked vegetables or canned or processed foods, and while their confidence in the safety of lettuce and spinach might be low following an attack on that sector, the fear and uncertainty would likely only be felt by that particular sector, and be measured purely by economic impact to that sector. Fear and uncertainty would not likely cross over into the general public and therefore not meet the concept of escalation.

4. Does the combination of casualties, economic disruption, and/or fear and uncertainty meet the threshold of escalation?

The combination of these three factors makes an agroterror attack more significant than when evaluating one factor individually. However, as discussed above, although the public response to large scale terrorist attack is harder to measure or estimate than pure economic impacts, it is unlikely that agroterror would have the overall impact that more conventional attacks have had, both in the U.S. and internationally.

5. Is it likely that an agroterror attack would be largely contained by the systems in place? Would multiple attacks likely overwhelm those systems?

The FMD case study shows the U.S. livestock industry is vulnerable to a FMD attack. Livestock is highly concentrated, accessible, and vulnerable to introduction of this highly contagious disease, and the resulting epidemic would be rapid and widespread. While this vulnerability might lead one to believe livestock poses an attractive target for potential attack, the impact of the attack must be evaluated. National containment measures would be implemented immediately, and while they might not stop the spread of the disease (as in the U.K. case) they would ensure the diseased animals did not enter the food supply. Ongoing recovery efforts would be both expensive and lengthy, but would likely be successful in eradicating the disease and reestablishing the safety and health of U.S. livestock. The established systems within the U.S. would largely be effective in identifying and responding to a FMD attack; while the system may respond too slowly to prevent an epidemic, it would likely be effective reducing its impact on humans.

E. coli is more harmful to humans, but less contagious. In fact, the bacteria must be directly consumed in order to cause illness or death. As the Salinas case study shows, even a multi-crop intentional contamination would run its course and even without concerted governmental effort, over time the contaminated produce would naturally disappear from the market. Therefore, the systems are adequate for response to a agroterror attack using bacterial agents such as *E. coli*. A contamination of this type would be largely self-limiting, and any government or industry response would accelerate this recovery, even if only moderately.

A successful FMD attack would be likely be so successful in spreading the disease and initiating an epidemic that successive attacks would not be necessary or have a dramatically different outcome. Any successive attack would extend the recovery period, but would not extend or increase the impact of the initial attack. Successive *E. coli* attacks however, would have a moderately different outcome than a single attack. The impact would certainly be larger, although each successive attack would likely have a reduced overall affect. While contaminating different sources might initially

complicate source identification, the dispersion of health care providers that would be instrumental in identifying the illnesses would enable the system to cope with an increased number of illnesses. Therefore, repeated attacks are not likely to overwhelm the systems in place.

B. CONCLUSION

While agroterror has the potential to cause illness, death, economic damage, and fear and uncertainty, it has inherent limitations as a tool of terror. It is not splashy and does not have the emotional impact of a conventional attack. This thesis has evaluated two different types of potential agroterror in order to determine if attacks on the U.S. could be significant enough in terms of escalation theory for an established terrorist organization to execute. The analysis shows that neither a FMD attack on livestock nor an *E. coli* attack on produce is likely to cause sufficient casualties, economic disruption, and/or fear and panic to constitute escalation from recent conventional attacks for an established international terrorist organization, and therefore agroterror attacks are not likely to be particularly attractive for such organizations.

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APPENDIX A. U.S. AGRICULTURAL EXPORTS

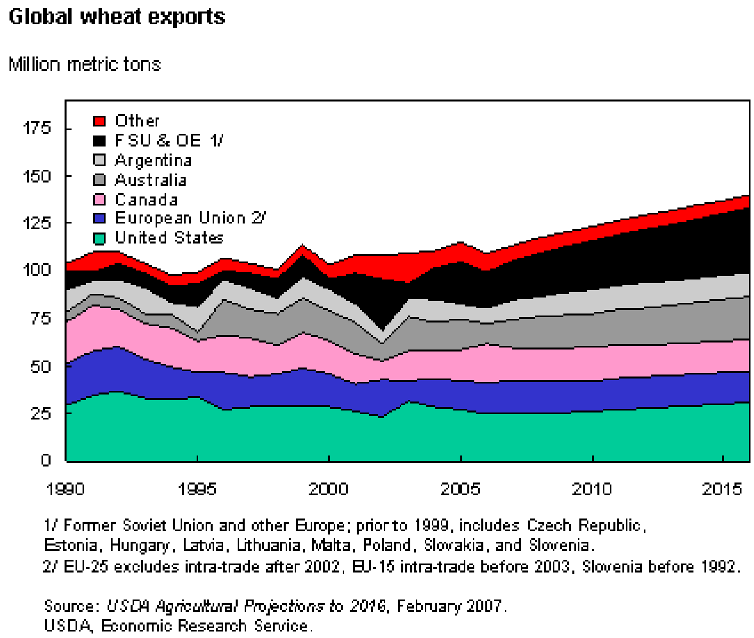

Figure 20. Global Wheat Exports.[162]

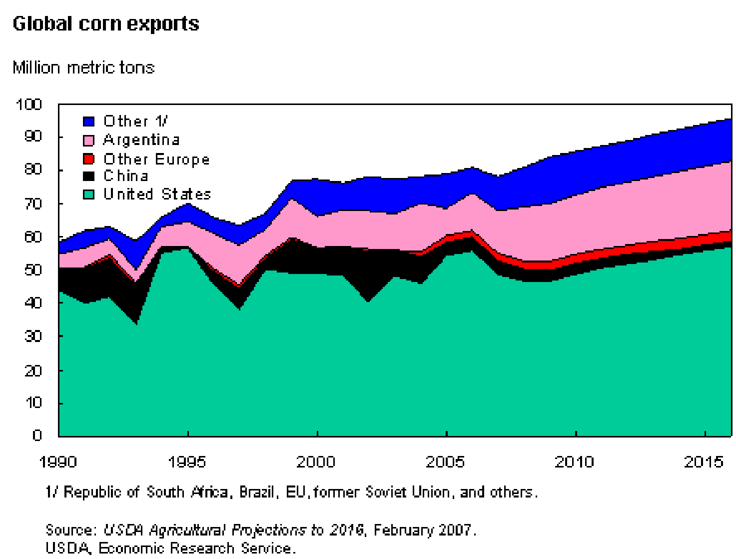

Figure 21. Global Corn Exports[163]

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[162]From USDA, "Agricultural Baseline Projections: Global Agricultural Trade, 2007-2016," http://www.ers.usda.gov/Briefing/Baseline/trade.htm (accessed 21 August 07).

[163] From Ibid.

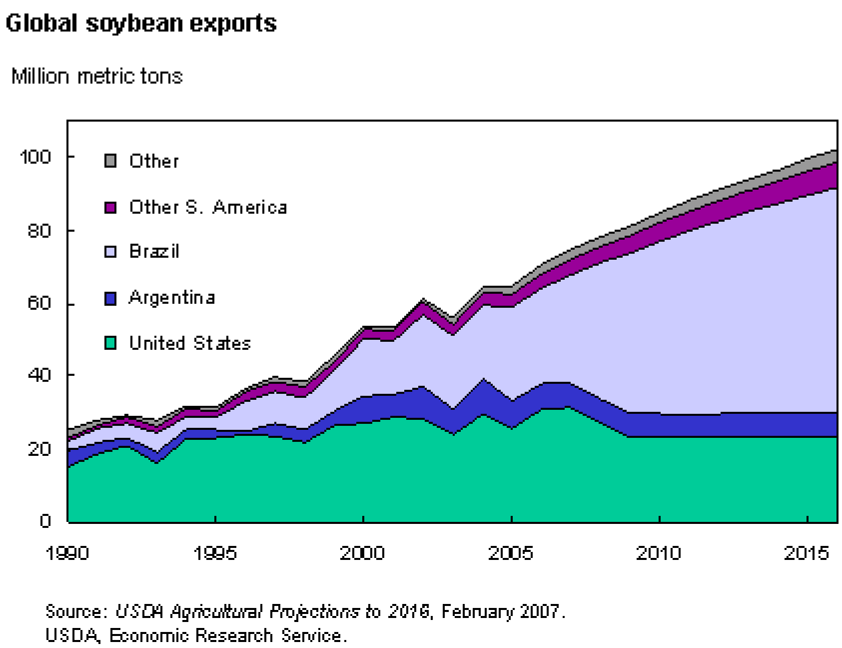

Figure 22. Global Soybean Exports[164]

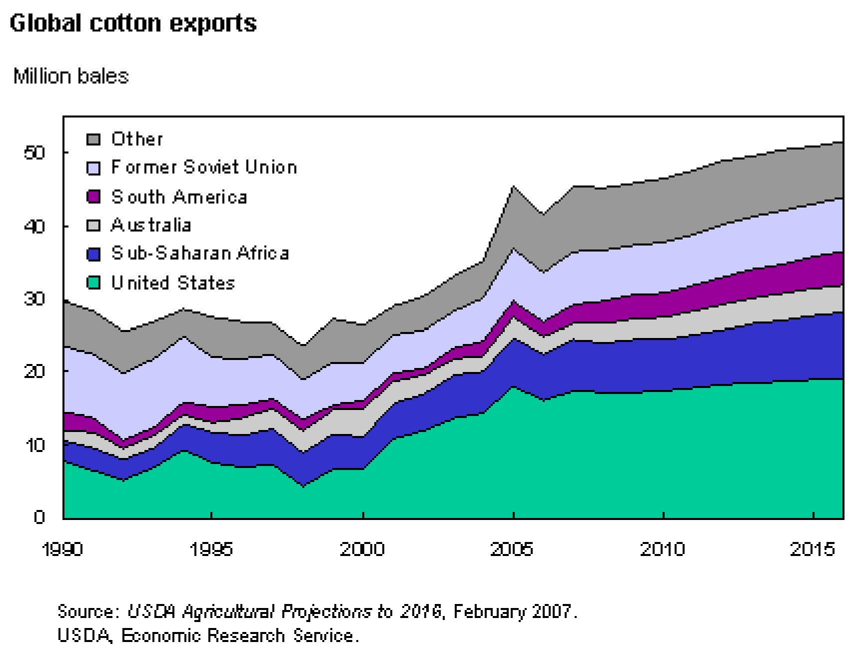

Figure 23. Global Cotton Exports[165]

[164] From USDA, "Agricultural Baseline Projections."

[165] From Ibid.

APPENDIX B. U.S. MEAT EXPORTS

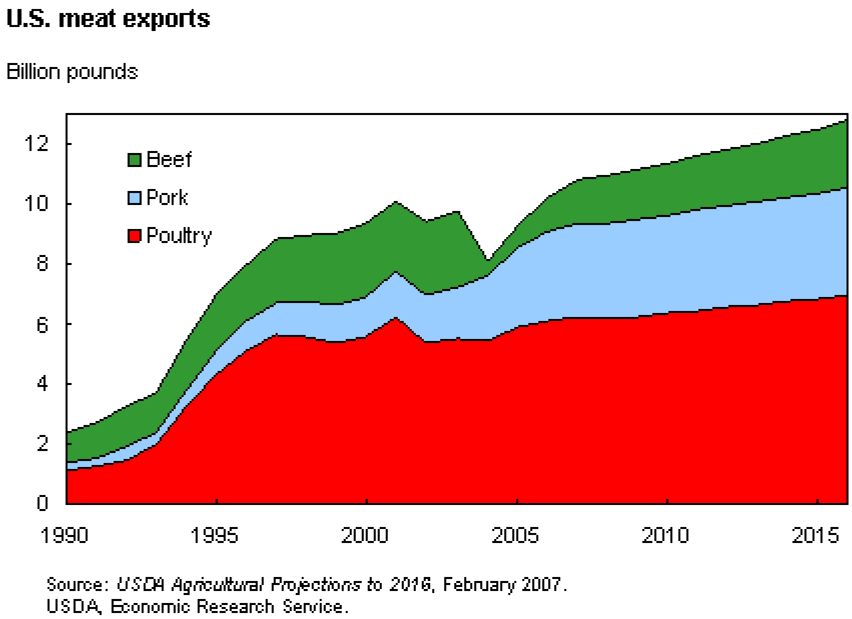

Figure 24. U.S. Meat Exports [166]

166 From USDA, "Agricultural Baseline Projections.".

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APPENDIX C. OIE LIST A AND LIST B DISEASES[167]

OIE LIST A AND LIST B DISEASES

Article 1.1.2.1. The following diseases are included in *List A*:

Foot and mouth disease
Vesicular stomatitis
Swine vesicular disease
Rinderpest
Peste des petits ruminants
Contagious bovine pleuropneumonia
Lumpy skin disease
Rift Valley fever
Bluetongue
Sheep pox and goat pox
African horse sickness
African swine fever
Classical swine fever
Highly pathogenic avian influenza
Newcastle disease.

Article 1.1.2.2. The following diseases are included in *List B*, (multiple species diseases):

Anthrax
Aujeszky's disease
Echinococcosis/hydatidosis
Heartwater
Leptospirosis
Q fever
Rabies
Paratuberculosis
New world screwworm
Old world screwworm
Trichinellosis.

Article 1.1.2.3. The following diseases are included in *List B*, (cattle diseases):

Bovine anaplasmosis
Bovine babesiosis
Bovine brucellosis
Bovine genital campylobacteriosis
Bovine tuberculosis
Bovine cysticercosis
Dermatophilosis
Enzootic bovine leukosis
Haemorrhagic septicaemia
Infectious bovine rhinotracheitis/ infectious pustular vulvovaginitis
Theileriosis
Trichomonosis
Trypanosomosis (tsetse-transmitted)
Malignant catarrhal fever
Bovine spongiform encephalopathy

Article 1.1.2.4. The following diseases are included in *List B*, (sheep and goat diseases):

Ovine epididymitis (*Brucella ovis*)
Caprine and ovine brucellosis (excluding *B. ovis*)
Caprine arthritis/encephalitis
Contagious agalactia
Contagious caprine pleuropneumonia
Enzootic abortion of ewes (ovine chlamydiosis)
Ovine pulmonary adenomatosis
Nairobi sheep disease
Salmonellosis (*S.* abortusovis)
Scrapie
Maedi-visna.

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Article 1.1.2.5. The following diseases are included in *List B*, (equine diseases):

Contagious equine metritis
Dourine
Epizootic lymphangitis
Equine encephalomyelitis (East and West)
Equine infectious anaemia
Equine influenza
Equine piroplasmosis
Equine rhinopneumonitis
Glanders
Horse pox
Equine viral arteritis
Japanese encephalitis
Horse mange
Surra (*Trypanosoma evansi*)
Venezuelan equine encephalomyelitis.

Article 1.1.2.6. The following diseases are included in *List B*, (swine diseases):

Atrophic rhinitis of swine
Porcine cysticercosis
Porcine brucellosis
Transmissible gastroenteritis
Enterovirus encephalomyelitis
Porcine reproductive and respiratory syndrome.

Article 1.1.2.7. The following diseases are included in *List B*, (avian diseases):

Avian infectious bronchitis
Avian infectious laryngotracheitis
Avian tuberculosis
Duck virus hepatitis
Duck virus enteritis
Fowl cholera
Fowl pox
Fowl typhoid
Infectious bursal disease (Gumboro disease)
Marek's disease
Avian mycoplasmosis (*M. gallisepticum*)
Avian chlamydiosis
Pullorum disease.

Article 1.1.2.8. The following diseases are included in *List B*, (lagomorph diseases):

Myxomatosis
Tularemia
Rabbit haemorrhagic disease.

Article 1.1.2.9. The following diseases are included in *List B*, (bee diseases):

Acariosis of bees
American foulbrood
European foulbrood
Nosemosis of bees
Varroosis.

Article 1.1.2.10. The following disease is included in *List B*, (other diseases):

Leishmaniosis

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